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Committee for Coordination of Investigations
of the Lower Mekong Basin.
(Cambodia, Laos, Thailand and Viet-Nam)

REPORT ON THE OPERATION OF A BARRAGE ON THE TONLE SAP

by

F. D'AUBENTON

Head of the Fisheries Mission

MUSEUM NATIONAL D'HISTOIRE NATURELLE

FRENCH REPUBLIC

MINISTRY OF FOREIGN AFFAIRS

FRENCH MISSION FOR ECONOMIC AND TECHNICAL ASSISTANCE

TO CAMBODIA

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INTRODUCTION

The two main reasons why this survey was undertaken are as follows:
- the alleged reduction of the number of fish in the Great Lake;
- the Mekong valley development projects.

Discussions on the reduction of the number of fish in the Great Lake are nothing new. P. Chevey and F. Le Poulain (1939) report that in 1907 fishermen were already complaining about the dwindling of the fish supply. In fact, there still seems to be an abundance of fish in the Great Lake, but chiefly small specimens of lesser commercial value. It is much more a question of size than a question of quantity. This is probably due to the increasing numbers of the Cambodian population which has to fish more and more in order to cover its ever increasing food requirements.

The Mekong valley development projects include the construction of several dams, one of which on the Tonle Sap. Now, it is a fact of common knowledge, illustrated by what happened in other countries, that the construction of such a dam can interfere with and even stop the movements of some varieties of fish.

In 1959, a preliminary mission of two months' duration was entrusted to Mr. M. Blanc, Assistant Director at the Museum National d'Histoire Naturelle, to establish the required contacts and examine the methods through which these important problems might be studied. The first mission also stressed how risky it would be to build a dam without studying the consequences on the upstream or downstream moves of many fish varieties.

Shortly afterwards, France accepted to undertake the biological and ecological survey of Cambodian soft-water fish life and the Museum National d'Histoire Naturelle assumed the scientific responsibility for this work. This is how the Fisheries Mission for which we are responsible was created. The field work started in June 1960. Subsequently, this Mission was joined by a technical agent, Mr. M. Fily, and was given the part-time assistance of a botanist, Mr. M. Schmid, Professor at the Ecole Nationale d'Agriculture in Saigon. It finally was also helped by a sedimentation and hydrology team including Mr. B. Dussart (Oct. - Dec. 1960), then Messrs. J.P. Carbonnel and G. Guiscafre (from January 1962).

/Mr. Bredillet,

Mr. Bredillet, a chemist of the Institut Pasteur, Phnom Penh, provided the physical chemical daily and monthly analyses of the water of the Mekong and the Tonle Sap, as well as of various sites from the lake, the flooded area, and the stungs.

All the observations made by the Fisheries Mission are not included in this report, whose sole purpose is to establish provisions for the operation of the dam. The remainder will be published later.

We wish to express our appreciation to the Service des Pêches of Cambodia for its cooperation and its constant interest in our work, especially to Mr. Dom Savoeun, Director of this Service; Mr. Kry, Fisheries Inspector, and Messrs. Sao Lieng and Swa Kret, Regional Directors for Phnom Penh and the Great Lake.

THE MAIN BIOTOPES

From the view point of the milieu we shall distinguish:

I. Water-courses whose flow is continuous or discontinuous (torrential)

II. Water-courses which during the year reverse their flow under the influence of the flood

III. Flooded areas proper

IV. Flooded depressed areas retaining water throughout the year.

These different biotopes group in each one of these categories:

I. the river, the tributaries, the stungs;

II. the preks;

III. the back-of-the-banks flooded areas;

IV. the lakes, the bengs.

I. THE RIVER, THE TRIBUTARIES, THE STUNGS

The Mekong river, 4,200 km. long, flows through Cambodia over a length of 480 km. The Cambodian part of the river can be divided into two sectors that will be described below.

The beginning of the Mekong floods is mainly caused by the melting of the snow in the Tibet; then by the rains on the various watersheds of the tributaries.

The flood period extends from the end of May or the beginning of June to the end of September or early October.

The beginning of the low stages season varies according to the reaches: that is March-April for the region of Stung Treng and Kratié, and from March 15 to May 15 for the region of Kompong Cham and Phnom Penh (See Flood chart).

In Phnom Penh there is the area of Quatre-Bras (Mekong, Bassac and Tonle Sap) which serves the basin of the Great Lake.

For the purposes of our study, we distinguished two sectors corresponding to two different biotopes on the Cambodian Mekong. The first sector extends from the Laotian border (downstream of Khone Falls) to Kratié (downstream of Sambor Rapids). The second sector extends from Kratié to Phnom Penh, downstream from Quatre-Bras.

/ First Sector

First Sector

The riverbed is deep, rocky, broken by rapids and shallow areas; troughs 40 to 60 m. deep are found along this reach. Large islands divide the riverbed into several arms, some of which become isolated from the mainstream in the dry season. The banks as well as the islands are covered with forest.

In this sector, the main tributaries which influence the Mekong water during the rainy season are located in the North, on the left bank of the river: they are the Se San, Sre Pok, Se Kong which start from the Annam Cordillera and meet at Stung Treng before flowing into the Mekong. Still on the left bank, other lesser tributaries like the Prek Té and the Prek Chlong are found upstream and downstream from Kratié. In this sector, the Mekong water flows rapidly (8-10 knots), making navigation very difficult during the high water period; timber floating currently is the only method of utilization. In the dry season, sampans piloted by experienced boatmen are the only kind of craft used on this reach.

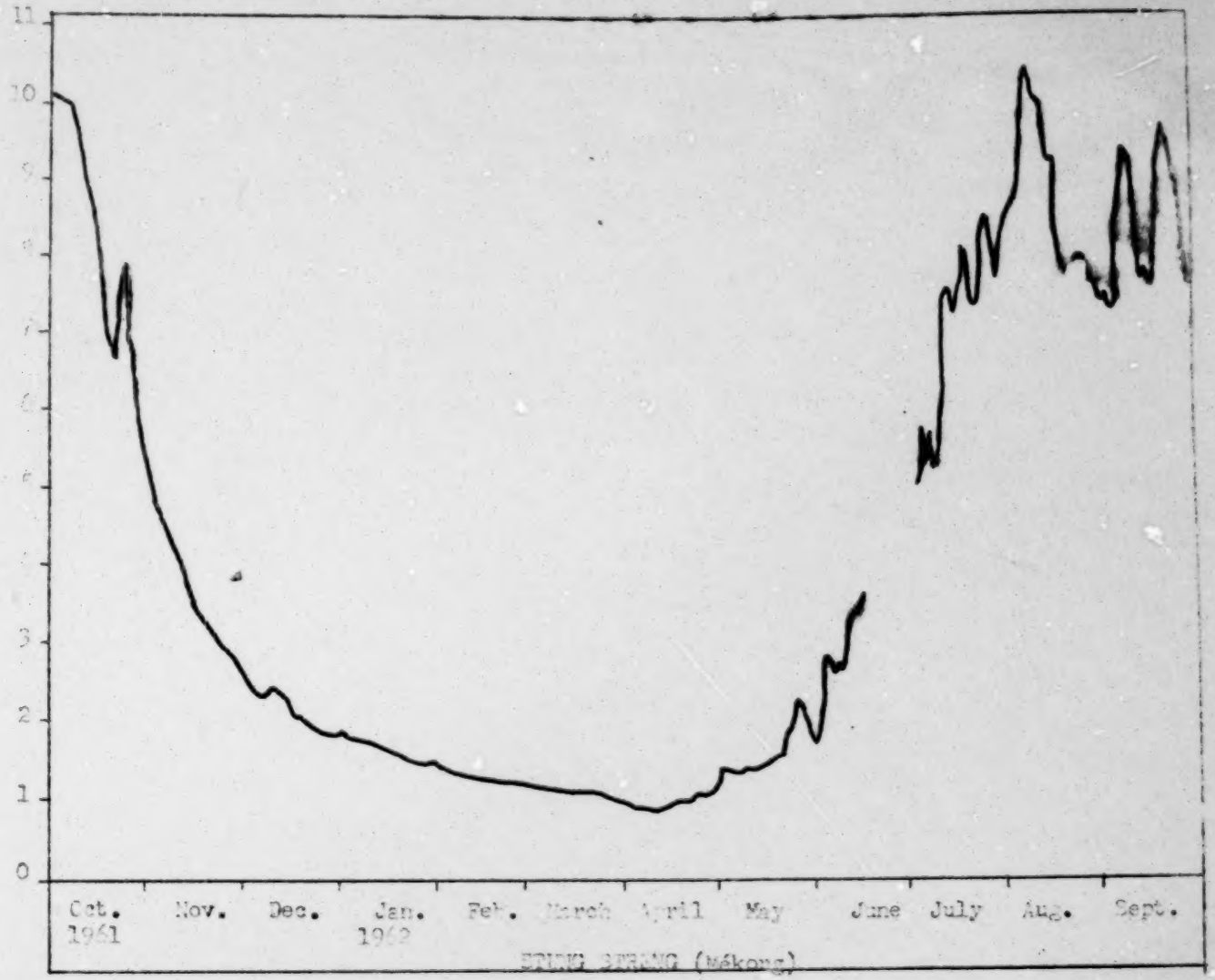
Very little fishing is done on this section of the Mekong excepting the region of Stung Treng where seasonal fishing for the local market is conducted. In this sector, big specimen of several fish varieties represented in the downstream reaches can be found, such as:

Dyasatis Bleekeri
Notopterus notopterus
Leptobarbus hoeweni
Probarbus julieni
Puntius bramoides
Cirrhinus auratus
Cybium cambodgiense
Pseudociena soldado
Pangasius Larnaudii
Pangasius sanitwongsei
Pangasius nasutus
Pangasianodon gigas
Kryptopterus apogon
Osphronemus goramy
Synaptura orientalis

Second Sector.

From Kratié downwards, the riverbed is sandy and flat; large and banks appear in the dry season. It also becomes narrower, and remains so right down to the Krauchmar loop. On both sides, large bengs begin to appear and the flooded

/ area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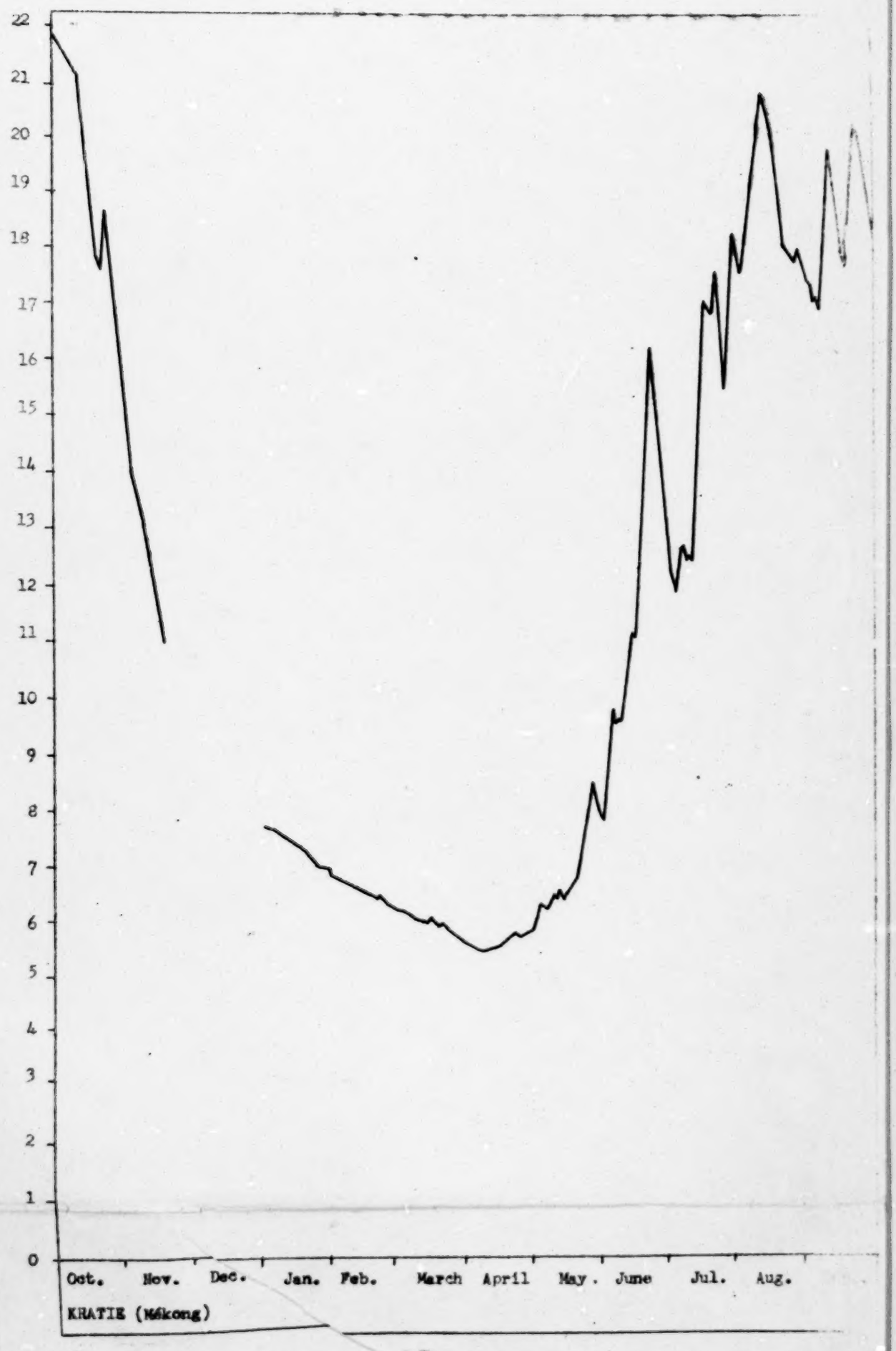
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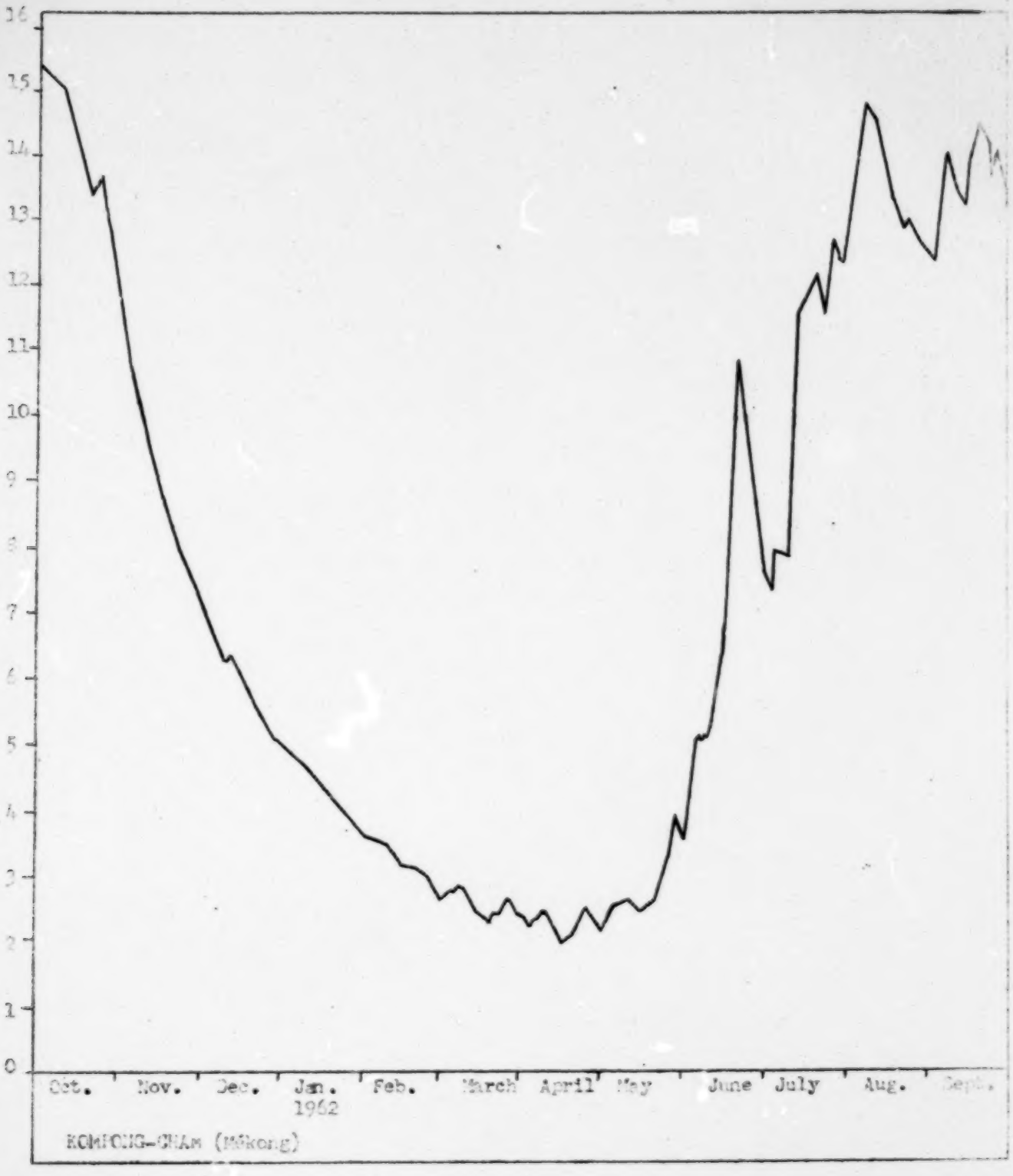
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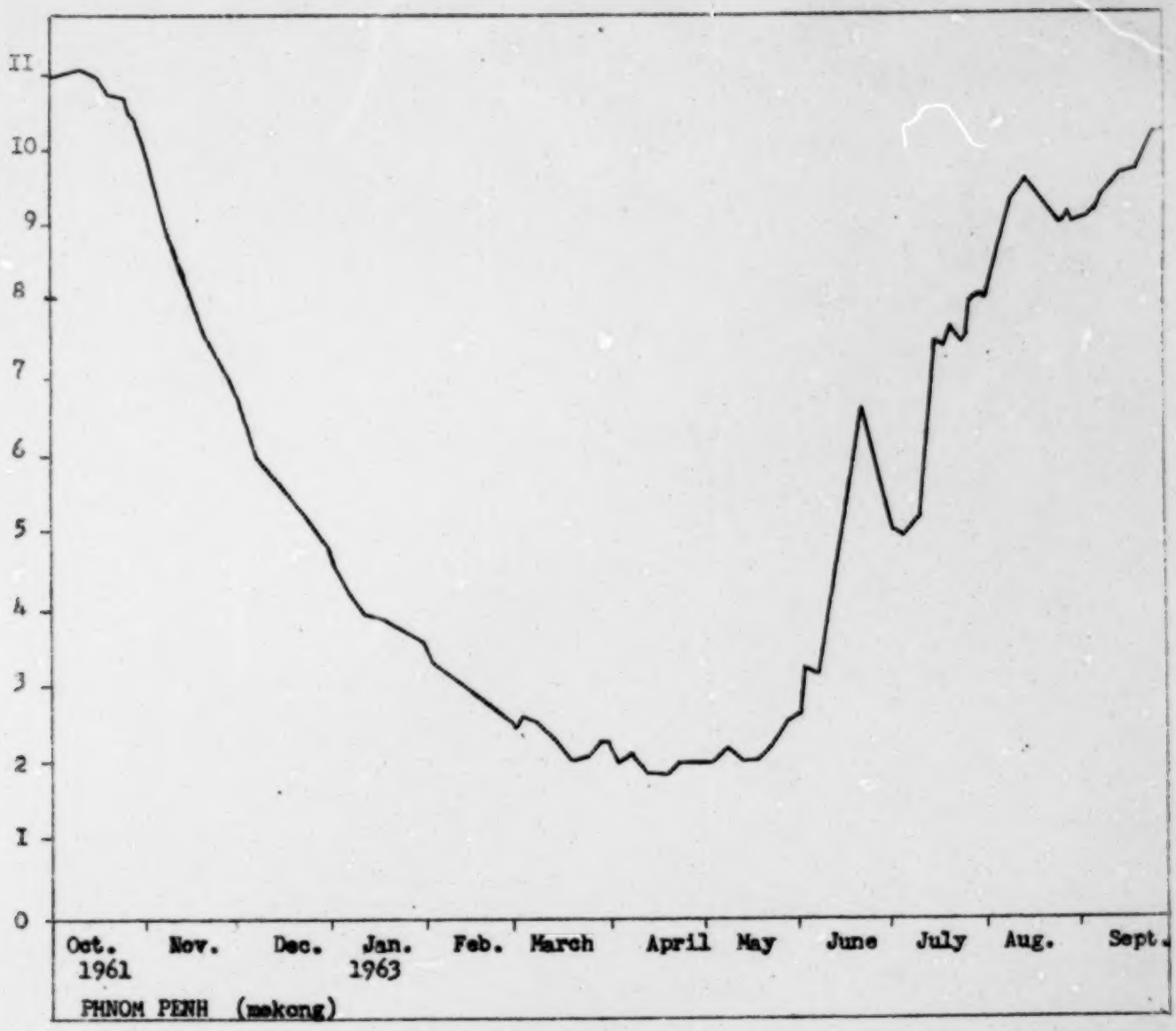
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area gets more and more extensive as one moves further downstream. Downstream from Kompong Cham, the Tonle Tauch, on the left bank, becomes a defluent during the high water period as far down as Banam and contributes, in addition to the river proper, to the flooding of the great plain of the Quatre-Bras loop.

Large islands are covered with grass, or cultivated. As the banks generally remain above water level, they are dotted with villages. The back-of-the-banks area communicates with the river through the preks, which are natural or artificial channels.

The flooded area is an alluvial plain partly covered with degraded forest mostly reduced to brush, small trees and bamboo copses. The ground is covered with short grass; many ponds and bengs retain their water during the dry season. This region is also utilized for growing maize, rice, etc.

The stungs or rivers are tributaries distributed around the great hydrographic axes; they mostly come from the watersheds northeast of the Cardamoms, South and Southwest of the Dangrek, and west of the Darlac uplands; their regime is closely associated with the rainfall. In some cases, the downstream section may be reversed at the beginning of the floods and is called a prek. In the dry season, the discharge of the stung is very much reduced.

Many streams called "O", with a torrential regime, carry little water to the river or to the lake during the rainy season, and usually dry up in the dry season.

The main stungs serving the Great Lake are:

East of the Lake	West of the Lake
Stung Sen	Stung Sisophon
Stung Stoung	Stung Monkolborrey
Stung Chikreng	Stung Sangker
Stung Roluo	Stung Dontri
Stung Siemreap	Stung Svidaun Keo
Stung Puok	Stung Pursat
Stung Sreng	Stung Kompong Lâ
Stung Svay Chek	Stung Babaur

For the Tonle Sap, Stung Chinit.

The fish life of the stungs is more or less attractive for fishing purposes, according to their depth and discharge. The most important are, for the Lake: Stung Sangker, joined by the Stung Treng, the Monkol Borey and Stung Svay Chek,

/ and Stung Sen.

and Stung Sen. Both these stungs are populated with Cyprinidae such as Cirrhinus auratus, Cirrhinus julieni, Thynnichthys thynnoides; Pangasidae such as Pangasius sutchi, Pangasius Lernaudi, Pangasius nasutus; Siluridae such as Cryptopterus apogon, Wallago attu; and Bagridae such as Macrones nemurus and Macrones vittatus which, during the high water period, provide the lake with a large breeding population.

II. THE PREKS

The preks are comparatively narrow channels connecting the river with the depressed back-of-the-banks areas; the most often end into bengs or ponds. Preks may be natural, but they mostly are canals dug out by man to promote the penetration of the silt-bearing waters during the floods into the depressions across the banks which, in the dry season, are utilized for cultivation purposes.

The regime of the preks therefore varies according to the season; their flow is reversible.

We observe that natural preks usually retain their water all the year round and so preserve a certain density of fish life.

These connecting "doors" are largely used by the fish and, as the waters ebb, provide valuable fishing sites.

The Tonle Sap

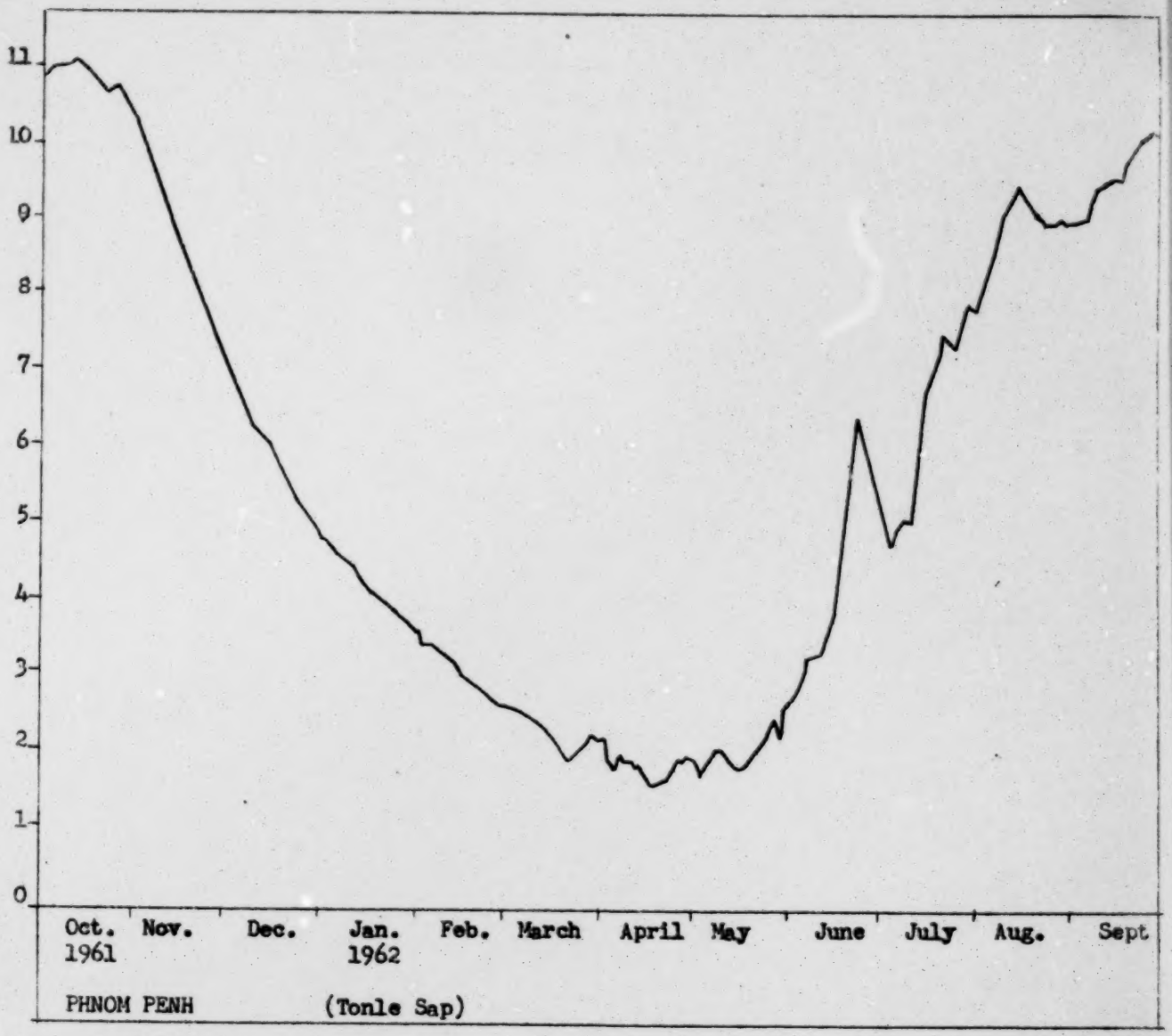
The Tonle Sap, a great connecting artery between the Mekong and the Great Lake, extends over approximately 120 km. from Quatre-Bras to Veal Pok, collecting on its way the water of Stung Chinit, downstream of Kompong Chhnang.

The flood begins to be felt in the early part of May. The waters of the Mekong gradually penetrate as far as Prek Kdam; then towards the end of May, or the beginning of June, the great flood of the Mekong begins. Very soon, these waters exceed the evacuation possibilities of the lower reaches, and they push the water of the Tonle Sap in the direction of the Great Lake. This is flow reversal time. In this first part of the flood developments, two stages have to be considered.

The first one is the flowing of the water of the Tonle Sap towards the Great Lake; the second the flowing of the flood water of the Mekong through the Tonle Sap towards the Great Lake.

The ebbing of the Tonle Sap corresponds to the ebbing of the Mekong, which takes place about the middle of October or November; another reversal takes

/takes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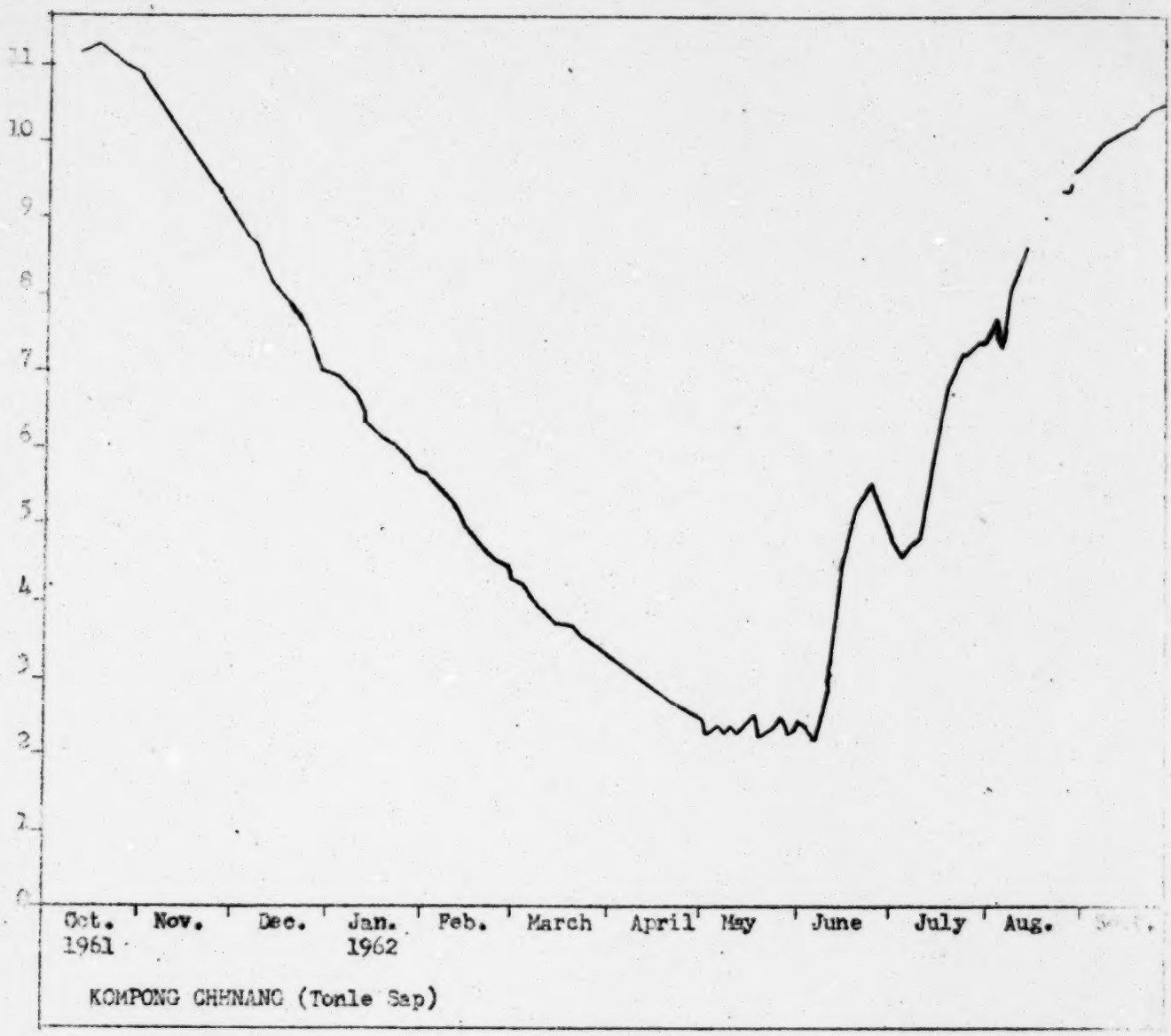
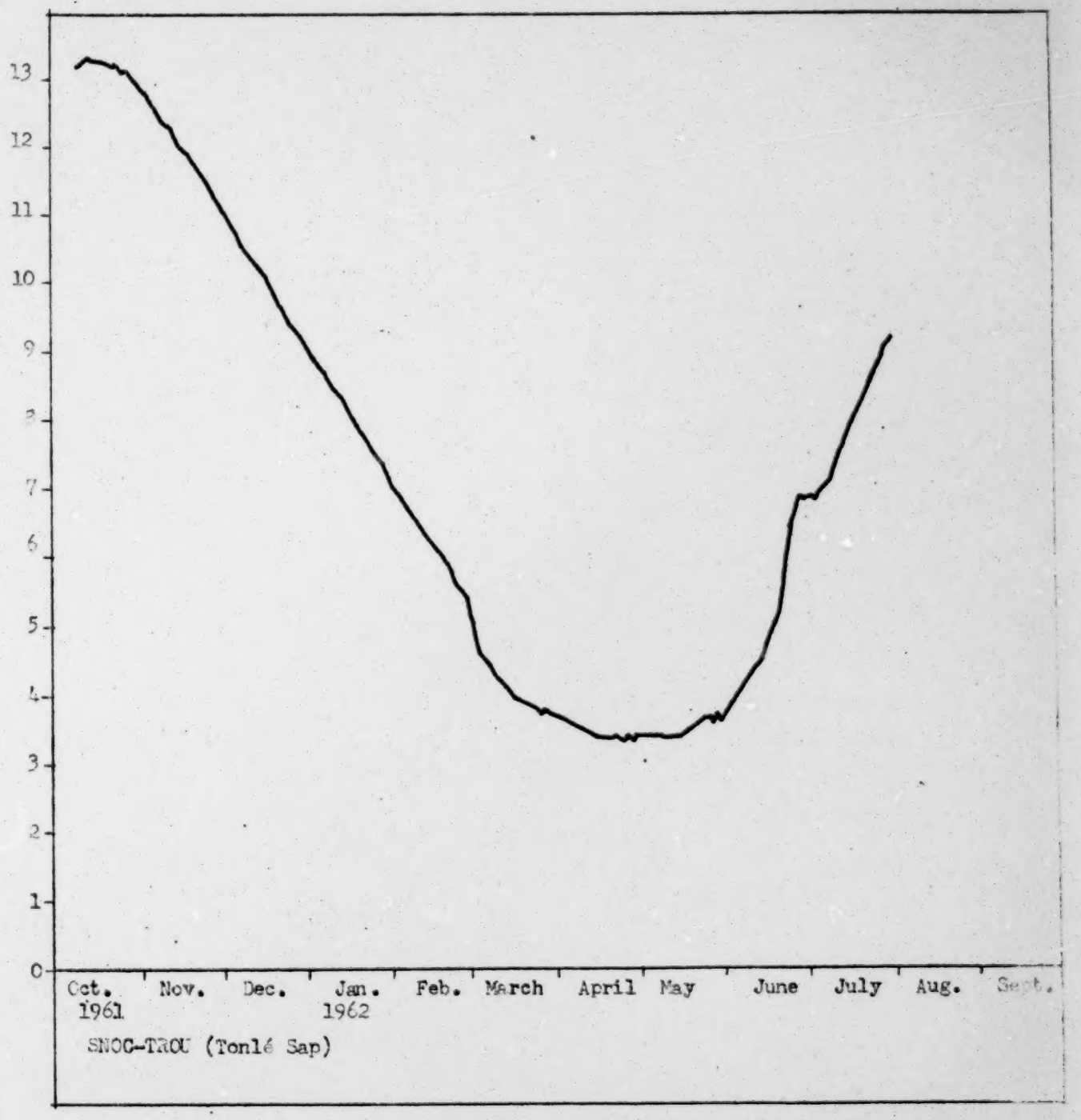
PHNOM PENH
(Tonle Sap)



KOMPONG CHHNANG (Tonle Sap)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SNOC-TROU (Tonlé Sap)

takes place in the direction of the Great Lake, towards Wuatre-Bras. The Tonle Sap must be considered as a huge natural prek, for it works in the same way as the others.

III. THE BACK-OF-THE-BANKS FLOODED AREAS

The silting-up of the edges of the river and of the Tonle Sap creates banks remaining practically always above the water level and on which villages have been built and crops are cultivated.

Behind these banks lie extensive depressions consituted by plains and bengs. Part of these plains is cultivated in the dry season, the other part being covered with bush-type vegetation.

This fertile back-of-the-banks areas also are frequented by the fish during the high water stages. They receive the river waters during the floods and collect the run-off of their own watersheds. A difference between the water levels is seen as the waters rise, owing to the small size of the inlets (the preks). The same thing occurs again in the opposite direction when the water ebbs, the back-of-the-banks water level being slightly above the river water level. These flooded lowlands partly contribute to the regulation of the flood.

IV. THE GREAT LAKE - THE BENGS

(a) The Great Lake

The Great Lake is an extensive depressed area in which three sections can be distinguished: the Great Lake proper, under the influence of the rains; the Small Lake, which also is under the influence of the Mekong water; and the Veal Pok, located downstream from Snoc Trou, which is the main stilling basin for the Mekong water.

The two first sections constitue an extensive depression narrower in its center, with a flat and uniform bottom, surrounded by the forest.

During the low water stages, the average depth varies from 0.70 - 0.80 m. to reach during the maximum stages of the flood a level varying from year to year between 10.05 (Kp. Luong des Lacs 1955) to 12.99 m. (Kp.Luong des Lacs 1952). This huge quantity of water gradually submerges the forest, reaching very far into the land on distance of 5 km. in the region of Snoc Trou, Kompong Luong des Lacs and 30 km. in the region of Stung Sang Ké and Tonle Chhmar.

/ The penetration

The penetration of the water into the flooded forest extends the realm of fish life which then finds a favourable region for breeding and abundant food: insects, leaves, invertebrates etc. and later a microfauna and microflora largely used by young fish and some adult varieties.

The utilization by the fish of the flooded area is not immediate, for the ecological process creates different zones which during one cycle cannot be frequented by all fish species.

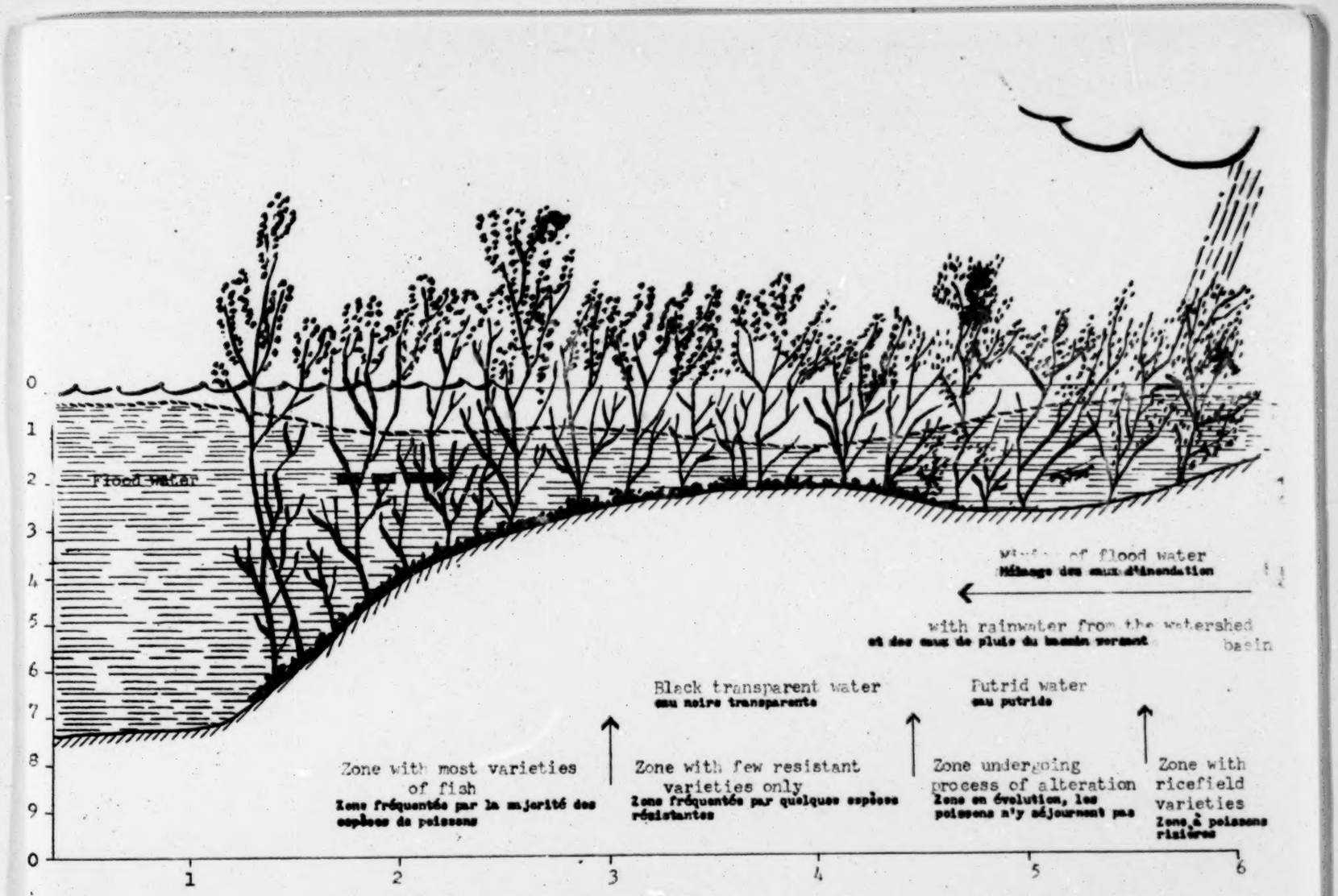
This is why we observe in the region of Snoc Trou, Kompong Luong des Lacs and Stung Sangker four zones which are characteristic of the gradual development of the cycle. The measurements made and the fishing done show that a whole section on the limits of the flooded area is practically not utilised, especially when the maximum of the flood is of short duration.

It is dissolved oxygen which mainly conditions the distribution of fish varieties. The quantity of this gas decreases as the putrefaction of vegetable matter is more recent. Another important factor is the ion reaction, or pH, which influences breeding; this for many species takes place between 6.5 and 7.5. The accompanying chart (22.8.61) shows the gradual evolution of the food water cycle. The zones which we indicate change and merge as the season advances. Eventually, there are only two zones remaining at the end of the flood period.

During the flood, most of the fish life frequents the first zone. Only asphyxiation-resisting kinds can stay there, such as:

Notopterus notopterus
Ophiocephalus micropeltes
Opiocephalus striatus
Pangasius sutchi (de petite taille)
Pangasius larnaudi
Trichogaster trichopterus
Trichogaster microlepis
Anabas testudineus
Clarias batrachus
Rasbora argyrotaenia
Rashora aurotaenia
Ompok bimaculatus
Macrones nemurus
Macrones vittatus
Ambassis microlepis
Ambassis ranga
Pristolepis fasciatus
Esomus danrica

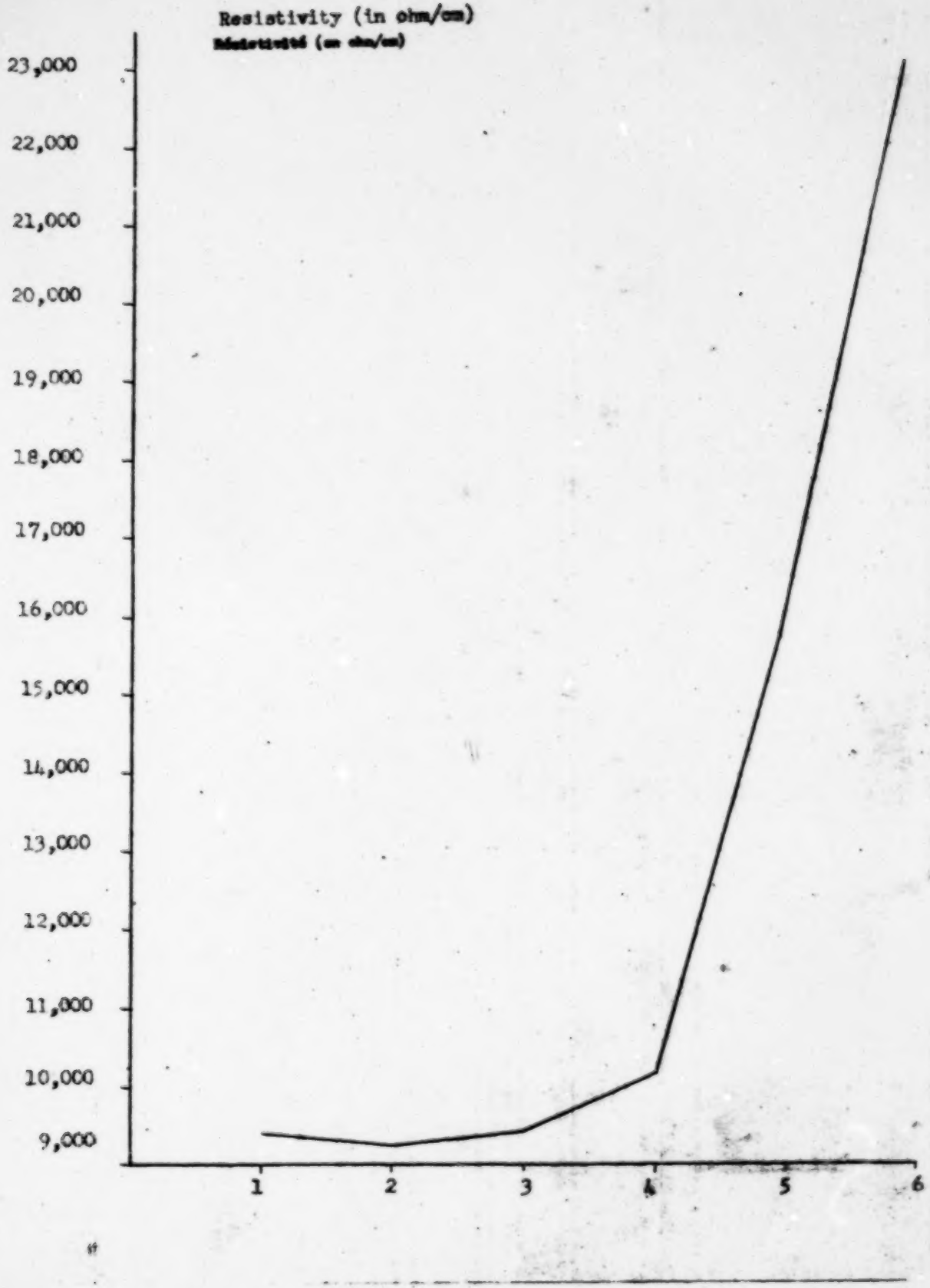
/ Some exchange

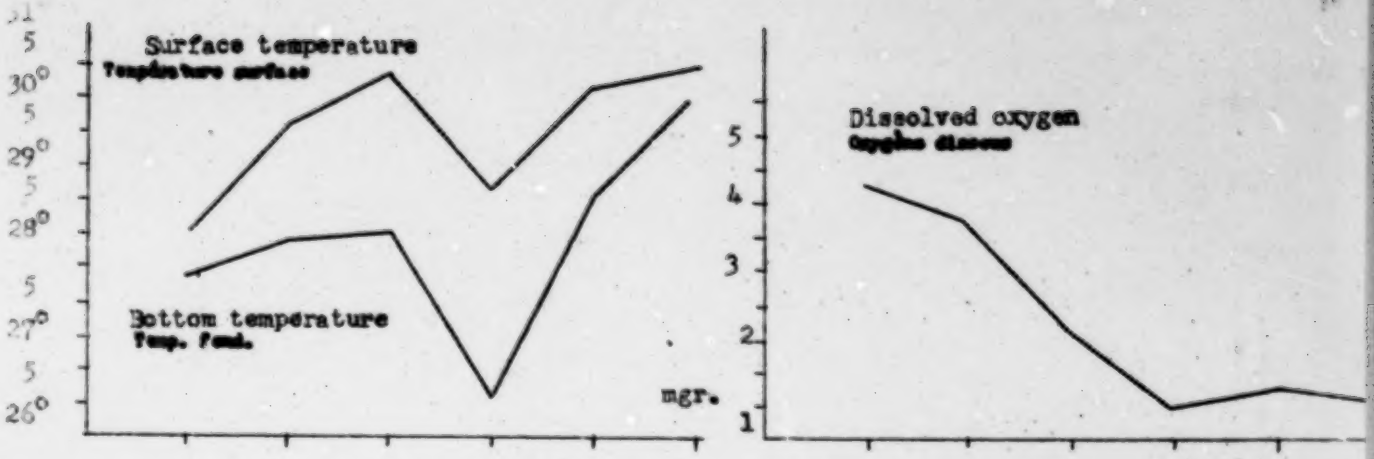


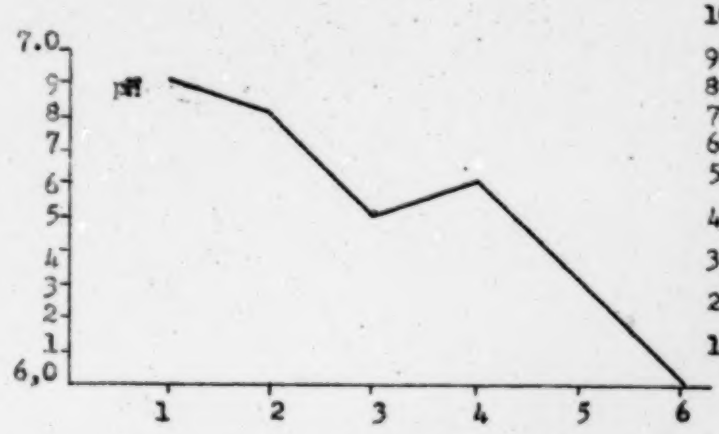
Oecological diagram of the flood process of the edges of the Great Lake at Snoc Trou, 22/8/61.

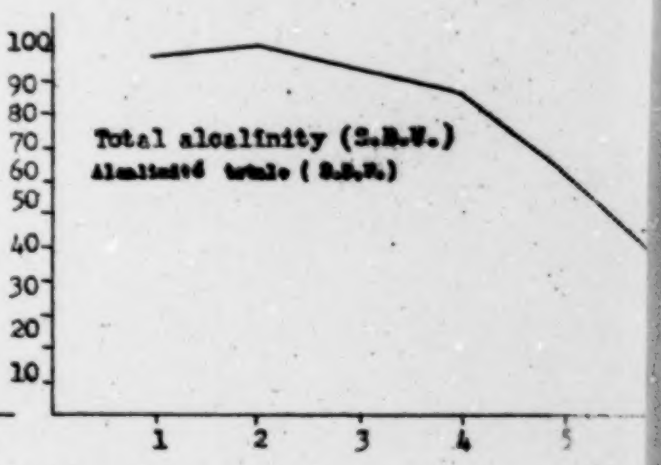
Schéma écologique du phénomène d'inondation des bords du Grand Lac à Snoc Trou, le 22/8/61.

Smoc-Trou, 22/8/61

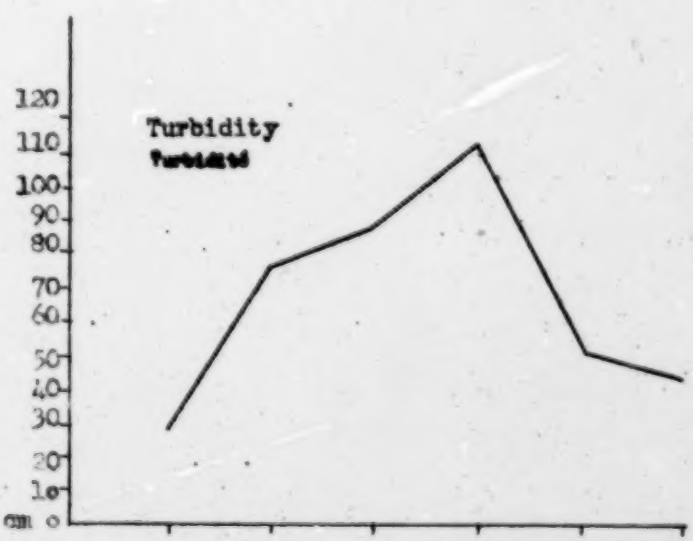


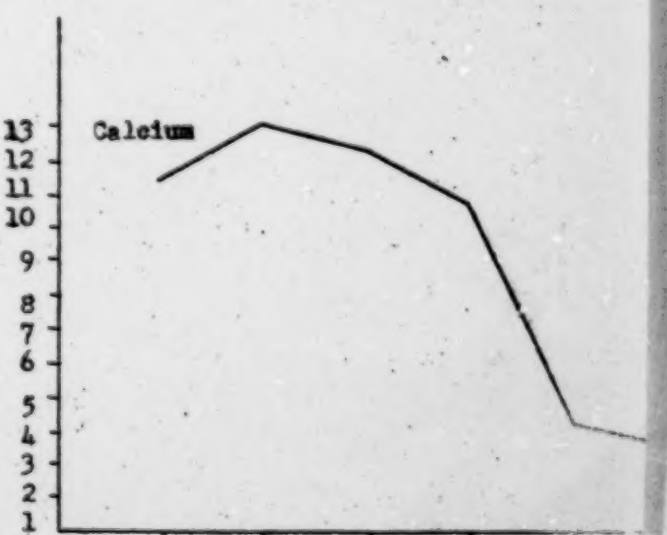


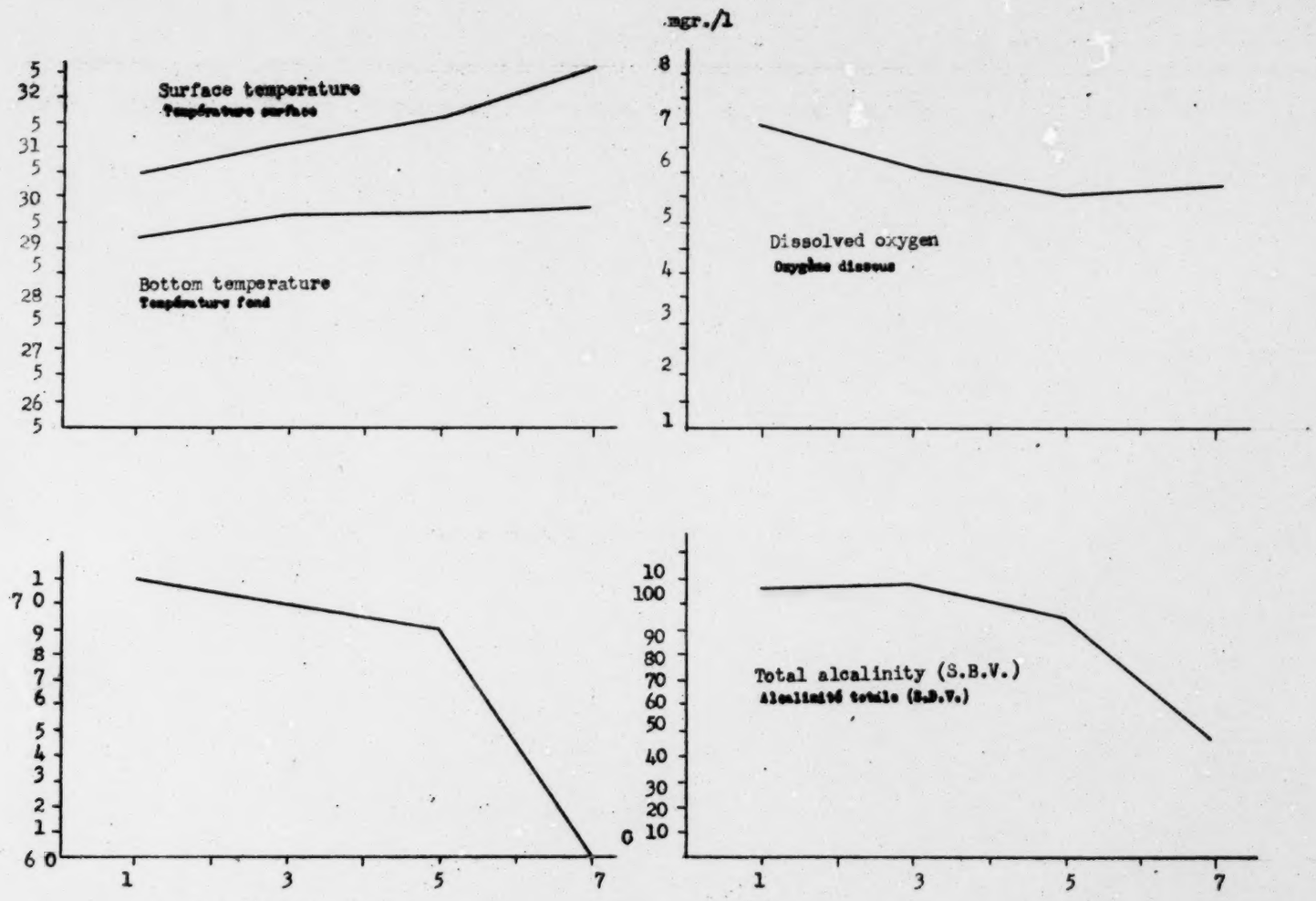




SNOC-TRCU, 22/8/61.



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Alcalinité totale (S.B.V.)
Base-Iron 1/11/61

Some exchange of fish life takes place between the peripheral ricefield zone and the resisting species zone; the composition is about the same excepting Pangasius sutchi, Pangasius Larnaudi, and Ophiocephalus micropeltes.

At the end of the cycle, that is, at the beginning of the ebbing period, the peripheral zone on the ricefields edge is the only one to remain differentiated.

From the milieu viewpoint we find (see chart for 1.11.62) that it has become stabilized; unfortunately, the ebbing water is no longer totally utilized for very many species already started upon the lateral migration which brings them back to the lake.

As the waters rise, it may happen that the flood is slowed down and that the run-off from the watersheds becomes higher as to the quantity of water reaching the lake. A real pollution then takes place. For the putrid water in the forest, pushed by rain water, flows back to the edges of the lake, of the preks or the stungs. Both fishes and eggs are then in a water unfit for their living conditions. We witnessed such a pollution in the region of Stung Sang Ké and Snoc Trou; a considerable number of young and old fish had died. We consulted the fishermen, who confirmed this process. It may take place in some years on a much more extensive scale and kill several tons of fish. We report this fact as significant.

(b) The bengs

These are troughs of various sizes located back of the banks and constituting ponds in the dry season, and subsequently included in the flooded area during the high water stages. They communicate through the preks with the hydrographic network.

The species remaining during the dry season mostly include:

Notopterus notopterus
Clarias batrachus
Bagarius bagarius
Macrones nemurus
Macrones vittatus
Ophiocephalus micropeltes
Ophiocephalus striatus
Anabas testudineus
Detnoides microlepis
Pristolepis fasciatus
Trichogaster microlepsis
Trichogaster trichopterus
Oxyelectris marmorata
Mastacembelus maculatus
Cirrhinus julieni

/ Some

Some bengs mostly located near the Mekong and the Tonle Sap retain:

Cirrhinus auratus
Cirrhinus julieni
Pangasius sutchi

The ecological process of the rising of the water is practically the same as for the Great Lake.

CAMBODIAN FISH LIFE

On the subject of Cambodian fish life, various studies have been published, mostly dealing with the economically valuable species. We thought it necessary to resume and complete these data into a new study based on the specimen collected in the course of this survey.

We shall publish later a systematic biological study of this fauna.

In this report, we merely list the Cambodian varieties which are currently known, presenting them according to the current classification.

Class of the Chondrichthyans

Sub-class of Selacians

Super-order of Euselacians

Series of Pleurotremes.

Order of Galeiforms (or Lamniforms).

Sub-order of Carcharhinoidei.

Family of Carcharhinidae.

Genus Scoliodon: Scoliodon sarrakowah (Ruessel)
Scoliodon walbeehmii (Bleeker)

Series of Hypotremes.

Order of Rajiforms.

Sub-order of the Rhinobatoidei.

Family of Pristidae.

Genus Pristis : Pristis microdon Latham

Sub-order of Dasyatoidei.

Family of Dasyatidae (or Trygonidae)

Genus Dasyatis : Dasyatis imbricatus (Schneider)
Dasyatis Krempfi Chabanaud

Class of the Osteichthyans

Sub-Class of Actinopterygians

Super-order of Teleosteans

Order of Clupeiforms.

Sub-order of Notopteroidiei.

Family of Notopteriadae.

Genus Notopterus : Notopterus chitala (H.B.)
Notopterus notopterus (Pallas)

Sub-order of Osteoglossoidei.

Family of Osteoglossoidae.

Genus Scleropages : Scleropages formosus (Mueller and Schlegel)

Sub-order of Clupeoidei.

Family of Clupeidae.

Genus Clupea : Clupea (Alosa) Kanagurta -(Bleeker)
Clupea (Alosa) Thibeaudeaui Durand

Genus Clupeoides : Clupeoides borneensis (Bleeker)

Genus Corica : Corica (Clupeichthys) goniognathus (Bleeker)

.../

Family of Engraulidae.

Genus Coilia : Coilia macrognathus Bleeker,
var. acquidentata Chab.

Genus Lycothrissa : Lycothrissa crocodilus (Bleeker)

Genus Setipinna : Setipinna melanochir (Bleeker)

Order of Tetraodontiforms.

Sub-order of Tetraodontoidei

Family of Tetraodontidae.

Genus Chonerhinus : Chonerhinus modestus (Bleeker)

Genus Tetraodon : Tetraodon cambodgiense Chabanaud

Order of Cypriniforms.

Family of Cyprinidae.

Genus Albulichthys : Albulichthys Krempfi Pellegrin et Chevey

Genus Amblirhynchichthys : Amblirhynchichthys altus Vaillant
Amblirhynchichthys truncatus (Bleeker)

Genus Balantiocheilus : Balantiocheilus melanopterus (Bleeker)

Genus Barbichthys : Barbichthys laevis (Cuvier-Valenciennes)

Genus Barilius : Barilius guttatus (Day)

Genus Catlacarpio : Catlacarpio siamensis Boulenger

Genus Chela : Chela coeruleostygmata (H.M. Smith)
Chela mouhoti H.M. Smith

Genus Cirrhinus : Cirrhinus auratus Sauvage
Cirrhinus Jullieni Sauvage

Genus Cosmochilus : Cosmochilus Harmandi Sauvage
Cosmochilus Pellegrini Durand

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Genus Crossochilus	: Crossochilus cambodgiensis Tirant
	Crossochilus cobitis (Bleeker)
	Crossochilus gnathopogon (Weber and de Beaufort)
	Crossochilus latius (H.B.)
Genus Cultrops	: Cultrops siamensis (Hora)
Genus Cyclocheilichthys	: Cyclocheilichthys apogon (Cuvier-Valenciennes)
	Cyclocheilichthys armatus (Cuvier-Valenciennes)
	Cyclocheilichthys enoplos (Bleeker)
	Cyclocheilichthys mekongensis Fowler
	Cyclocheilichthys repasson (Bleeker)
	Cyclocheilichthys siaja Bleeker
Genus Dangila	: Dangila Cuvieri Valenciennes in Cuvier-Valenciennes = D. leptocheilus van Hasselt.
	Dangila siamensis Sauvage
	Dangila spilopleura H.M. Smith
Genus Esomus	: Esomus danrica (H.B.)
Genus Gyrinocheilus	: Gyrinocheilus Aymonieri (Tirant)
	Gyrinocheilus Pennocki (Fowler)
	Gyrinocheilus pustulosus Vaillant
Genus Hampala	: Hampala macrolepidota van Hasselt, Cuvier-Valenciennes
Genus Labeo	: Labeo (Morulius) chrysophekadion (Bleeker)
	Labeo erythropterus (Cuvier-Valenciennes)
	Labeo pleurotaenia (Bleeker)
	Labeo pruol Tirant (may be = Cirrhinus auratus Sauvage)
	Labeo stygmapleura Fowler
Genus Leptobarbus	: Leptobarbus Hoevenii (Bleeker)

.../

Genus Luciosoma	: Luciosoma Bleekeri Stein Steindachner
	Luciosoma setigerum (Cuvier-Valenciennes)
Genus Macrochirichthys	: Macrochirichthys macrochirus (Cuvier-Valenciennes)
Genus Osteichilus	: Osteochilus brachynotopterus (Bleeker)
	Osteochilus Hasselti (Cuvier-Valenciennes)
	Osteochilus melanopleura (Bleeker)
	Osteochilus Schlegeli (Bleeker)
	Osteochilus spilopleura Fowler
	Osteochilus triporus (Bleeker)
	Osteochilus vittatus (Cuvier-Valenciennes)
Genus Oxygaster	: Oxygaster oxygastroides (Bleeker)
Genus Paralaubuca	: Paralaubuca Harmandi Sauvage
	Paralaubuca siamensis (Guenther)
	Paralaubuca stigmabrachium (Fowler)
	Paralaubuca typus Bleeker
Genus Probarbus	: Probarbus Jullieni Sauvage
Genus Puntioplites	: Puntioplites proctozysron (Bleeker)
Genus Puntius	: Puntius altus (Guenther)
	Puntius bramoides (Cuvier-Valenciennes)
	Puntius brevis (Bleeker)
	Puntius bulu (Bleeker)
	Puntius chola (H.B.)
	Puntius elongatus (Seale)
	Puntius javanicus (Bleeker)
	Puntius binotatus (Cuvier-Valenciennes)
	Puntius orphoides (Cuvier-Valenciennes)
Genus Rasbora	: Rasbora aurotaenia Tirant
	Rasbora argyrotaenia (Bleeker)
Genus Thynnichthys	: Thynnichthys thynnoides (Bleeker)

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Genus Tylognathus (or Lobocheilus): Tylognathus bo Popta
Tylognathus falcifer (Cuvier-Valenciennes)
Tylognathus Lehat Bleeker

Genus Varicorhinus : Varicorhinus dyocheilus (Mc.Clelland)

Genus Xenocheilichthys : Xenocheilichthys Loppei Durand

Family of Cobitidae.

Genus Acanthopsis : Acanthopsis cheriorynchus (Bleeker)

Genus Botia : Botia hymenophysa (Bleeker)
Botia modesta Bleeker
Botia Morleti (Tirant)

Sub-order of Siluroidei.

Family of Clariidae.

Genus Clarias : Clarias batrachus (L.)

Genus Prophagorus : Prophagorus nieuhofii (Cuvier-Valenciennes)

Genus Saccobranchus (or Heteropneustes :
Saccobranchus fossilis (Bloch)

Family of Schibeidae.

Genus Helicophagus : Helicophagus hypophthalmus Sauvage
Helicophagus Waandersi Bleeker

Genus Pangasianodon : Pangasianodon gigas Chevey

Genus Pangasius : Pangasius altifrons Durand
Pangasius Beani H.M. Smith
Pangasius Burgini Fowler
Pangasius Larnaudi Bocourt
Pangasius macronemus Bleeker
Pangasius micronemus Bleeker
Pangasius nasutus (Bleeker)

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Genus Pangasius (cont.)	: Pangasius pangasius (H.B.)
	Pangasius polyuranodon Bleeker
	Pangasius Sanitwongsei H.M. Smith
	Pangasius Sutchi Fowler
Genus Pteropangasius	: Pteropangasius cultratus H.M. Smith

Family of Siluridae.

Genus Belodontichthys	: Belodontichthys dinema (Bleeker)
Genus Callichrous (or Ompok)	: Callichrous bimaculatus (Bloch)
Genus Kryptopterus	: Kryptopterus apogen (Bleeker)
	Kryptopterus bicirrhis (Cuvier-Valenciennes)
	Kryptopterus Cheveyi Durand
	Kryptopterus kryptopterus (Bleeker)
	Kryptopterus micronema (Bleeker)
	Kryptopterus Schilbeides (Bleeker)
Genus Penesilurus	: Penesilurus bekerensis Pellegrin and Chevey
Genus Silurodes	: Silurodes hypophthalmus (Bleeker)
Genus Wallago	: Wallago attu (Bloch-Schneider)
	Wallago leerii Bleeker
	Wallago microstoma Vaillant

Family of Bagridae.

Genus Ambliceps	: Ambliceps mangois (H.B.)
Genus Arius	: Arius microcephalus Bleeker
Genus Bagarius	: Bagarius bagarius (H.B.)
Genus Bagrichthys	: Bagrichthys hypselopterus (Bleeker)
Genus Bagroides	: Bagroides macracanthus Bleeker
	Bagroides macropterus Bleeker
Genus Batracocephalus	: Batracocephalus mino (H.B.)

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Genus Hemipimelodus	: Hemipimelodus borneensis (Bleeker)
	Hemipimelodus cochloaris Fowler
	Hemipimelodus Daugueti Chevey
	Hemipimelodus macrocephalus Bleeker
	Hemipimelodus siamensis Sauvage
Genus Heterobagrus	: Heterobagrus Bocourti Bleeker
Genus Leiocassis	: Leiocassis albicollaris Fowler
	Leiocassis siamensis Regan
Genus Macrones	: Macrones micracanthus Bleeker
	Macrones nemurus (Cuvier-Valenciennes)
	Macrones planiceps (Cuvier-Valenciennes)
	Macrones nigriceps (Cuvier Valenciennes)
	Macrones rubicauda Bardach
	Macrones vittatus (Bloch)
	Macrones Wollfii (Bleeker)
	Macrones Wyckii (Bleeker)
Genus Osteogeneiosus	: Osteogeneiosus militaris (L.)

Family of Plotosidae.

Genus Plotosus : Plotosus canius H.B.

Order of Anguilliforms.

Sub-order of Anguilloidei.

Family of Anguillidae.

Genus Anguilla : Anguilla sp.

Sub-order of Congroidei.

Family of Ophichthidae.

Genus Ophichthys : Ophichthys rhitidoderma (Bleeker)

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Order of Symbranchiformes

Family of Symbranchidae.

Genus Monopterus : Monopterus albus (Zniew)

Genus Symbranchus : Symbranchus bengalensis (Mc.Clelland)

Order of Beloniforms.

Sub-order of Belonoidei.

Family of Belonidae.

Genus Tylosurus : Tylosurus strongylurus van Hasselt

Genus Xenentodon : Xenentodon cancilo'des (Bleeker)

Sub-order of Exocoetoidei.

Family of Hemiramphidae.

Genus Hemiramphus : Hemiramphus Mocquardianus Thominot

Genus Zenarchopterus : Zenarchopterus Buffoni (Cuvier-Valenciennes)
Zenarchopterus ectuntio (H.B.)

Order of Syngnathiforms.

Family of Syngnathidae.

Genus Microphis : Microphis boaja (Bleeker)

Genus Syngnathus : Syngnathus spicifer Rueppel

Order of Polynemiforms.

Family of Polynemidae.

Genus Polynemus : Polynemus berneensis Bleeker
Polynemus longipectoralis Weber and de Beaufort.

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Order of Perciforms.

Sub-Order of Percoidiei.

Family of Serranidae.

Genus Ambassis	: Ambassis ranga (H.B.) Ambassis Wolffii Bleeker
Genus Lates	: Lates calcarifer (Bloch)

Family of Nandidae.

Genus Nandus	: Nandus nebulosus (Gray)
Genus Pristolepsis	: Pristolepsis fasciatus

Family of Lobotidae.

Genus Datnioides	: Datnioides microlepsis Bleeker

Family of Sciaenidae.

Genus Pseudosciaena	: Pseudosciaena soldado (Lacépède)

Family of Toxotidae.

Genus Toxotes	: Toxotes chatereus (H.B.) Toxotes microlepsis Guenther

Sub-order of Anabantoidei.

Family of Anabantidae.

Genus Anabas	: Anabas testudineus (Bloch)
Genus Osphronemus	: Osphronemus goramy Lacépède Osphronemus siamensis Guenther
Genus Trichogaster	: Trichogaster microlopis (Guenther) Trichogaster pectoralis (Rogan) Trichogaster trochopterus (Pallas)

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Genus Trichopsis : Trichopsis vittatus (Cuvier-Valenciennes)

Sub-order of Ophicephaloidei.

Family of Ophiocephalidae.

Genus Ophiocephalus : Ophiocephalus gachua H.B.
Ophiocephalus lucius (Kuhl and van Hasselt) Cuvier-Valenciennes
Ophiocephalus melanopterus Bleeker
Ophiocephalus micropeltes (Kuhl and van Hasselt) Cuvier-Valenciennes
Ophiocephalus siamensis Guenther
Opiocephalus striatus Bloch

Sub-order of Gobioidei.

Family of Electridae.

Genus Oxyelectris : Oxyelectris marmoratus (Bleeker)

Family of Gobiidae.

Genus Glossogobius : Glossogobius giuris (H.B.)

Order of Pleuronectiforms.

Sub-order of Soleoidei.

Family of Soleidae.

Genus Synaptura : Synaptura Krempfi Durand
Synaptura orientalis (Bloch-Schneider)

Family of Cynoglossidae.

Genus Cynoglossus : Cynoglossus microlepis (Bleeker)

Order of Mastacembeliforms.

Sub-Order of Mastacembeleidei.

Family of Mastacembelidae.

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Genus Mastacembelus	: Mastacembelus argus Guenther
	Mastacembelus armatus Lacépède
	Mastacembelus circumcinctus (Hora)
	Mastacembelus favus (Hora)
	Mastacembelus maculatus Cuvier-Valenciennes
Genus Rhynchobdella	: Rhynchobdella aculeata (Bloch)

MIGRATIONS

This part of the survey is the most important as it concerns the movement of the fish and that the problem raised by the construction of the dam on the Tonle Sap is whether this construction will not result in a reduction of the fish production through a paralysis of the fish movements.

Fish are not sedentary unless they live in pools, natural or artificial ponds, etc. Collective movement or migration therefore is the general rule.

One usually distinguishes two kinds of migrations: those for breeding purposes, which are called genetic; and others for feeding purposes, which are called trophic. On their way to the breeding sites and during the breeding period, the fish do not eat; on the other hand, both young and adults, outside this period, consume huge quantities of food. This observation, made in temperate regions, led to the conclusion that the two kinds of migration were opposed. Actually, this opposition is due to the fact that breeding sites and feeding sites are generally not the same in temperate regions, whereas in tropical regions genetic migration and trophic migration frequently are merged in one movement, due to the seasonal occurrence of floods which provides the fish population with breeding sites and abundant food.

Migratory fishes can be divided into two groups:

(a) those who do not change their milieu; they are called holobiotic and can be either potamic holobiotic for soft water fish or thalassic holobiotic for sea-fish;

(b) those who change their environment are called amphibiotic. Among these, some lay their eggs in soft water, like salmon and alosa; others lay in the sea and grow in soft water like the European eel. Among the Cambodian kinds belonging to this category the Lates calcarifer (of which mostly young specimens are to be seen) and eels (in very small numbers) may be mentioned.

The reason for studying migrations is to find the reasons for these migrations, whether long or short; that is, their determinism.

The determinism of migrations is due to reflexes or tactisms imposed, occasioned and governed by the environment. In other words, the fish react to excitations from outside.

These are mainly connected with:

/thermotactism

thermotactism	-	reaction to heat
phototactism	-	reaction to light
halotactism	-	reaction to salt
chemiotactism	-	reaction to dissolved chemicals

Fish do not only react to the environment, they also react according to their physiological condition. For instance, a part is played by hormones produced by internal secretion glands, especially the thyroid and hypophyse. In the great migrating species, according to Fontaine, hormonal production is above average, which compels them to undertake extensive travelling for breeding purposes and makes their growth quicker than in sedentary types.

Tropical regions have two very clear-cut seasons:

- the rainy season, to which correspond the high water stages of the rivers and the flooding of the lowlands;
- the dry season, to which correspond the ebbing of rivers and low water stages.

The huge quantities of water coming from the uplands and the plains totally modify the biological conditions in which the fish lives during the dry season.

As we mentioned before, this change in the environment causes the reflexes or tactisms through which the fish react by starting upon their migration. These modifications of the environment then become a fundamental factor.

In order to distinguish these migrations of the fish of tropical regions, we use the general terms of longitudinal migrations and transversal migrations:

- Longitudinal migrations, anadromes or catadromes, i.e. the movements of fish following the river in its bed in either direction;
- Lateral migrations, for fish going from the normal riverbed towards flooded areas during the flood and leaving them when the water is receding.

Owing to the huge quantity of fish involved, the great extent of the

/ hydrographic

hydrographic network, and administrative difficulties, we had to consider a method other than marking. We regularly fished at each season in each one of the biotopes, which enabled us to locate the preferential site of each species according to the seasons, as well as to understand the pattern of migration.

Methodical control fishing was mainly done:

- for flood migrations in the Snoc Trou delta, from the beginning of the flood until the end of July, by means of "day" and "yors", the latter being a special device for catching very big specimens like Pangasianodon gigas. These observations involved quantities of fish in the amount of 26 tons.
- for ebb migrations, we fished with a "day" (i.e., a fixed drag-net) on the Tonle Sap at a distance of 9 km. from Quatre-Bras, from October to the end of February, thus controlling over 66 tons of fish with this sole device.

The remainder of the control fishing was conducted in the flooded forest by means of other devices.

- on the Great Lake through inspecting the operation of fisheries.
- on the Mekong, downstream from Kratié.

The Mekong Rapids between Stung Treng and Sambor were treated in two special visits with fishermen used to boating and fishing in this difficult section.

The observations and the data gathered are numerous and will be submitted separately.

For the sake of clarity we deliberately chose to submit in this report only general migration rules observed on the spot and on which the programme of operation of the dam can be used.

I. The accompanying general pattern of migration gives a precise idea of the movement of fish. It shows that most varieties except Cybium, Lates, Tylosurus, Xenentodon, Cirrhinus auratus, can indifferently be represented in all seasons, whether in the Great Lake or the second sector of the Mekong.

/ II.

II. Certain species such as Pangasius sutchi, Pangasius larnaudi, Pangasianodon gigas, Catlacarpio siamensis, are represented in the lake during the low water stages only by young specimens not exceeding 2 kg. in weight. Formerly, when fishermen were fewer, they happened to catch Pangasius sutchi weighing 4 to 5 kg. The adult weight for this fish is 5 kg.

III. Adult Pangasius sutchi stay during the low water stages in the deep regions of the Mekong or stungs. Adult Cirrhinus auratus has a preference for running water.

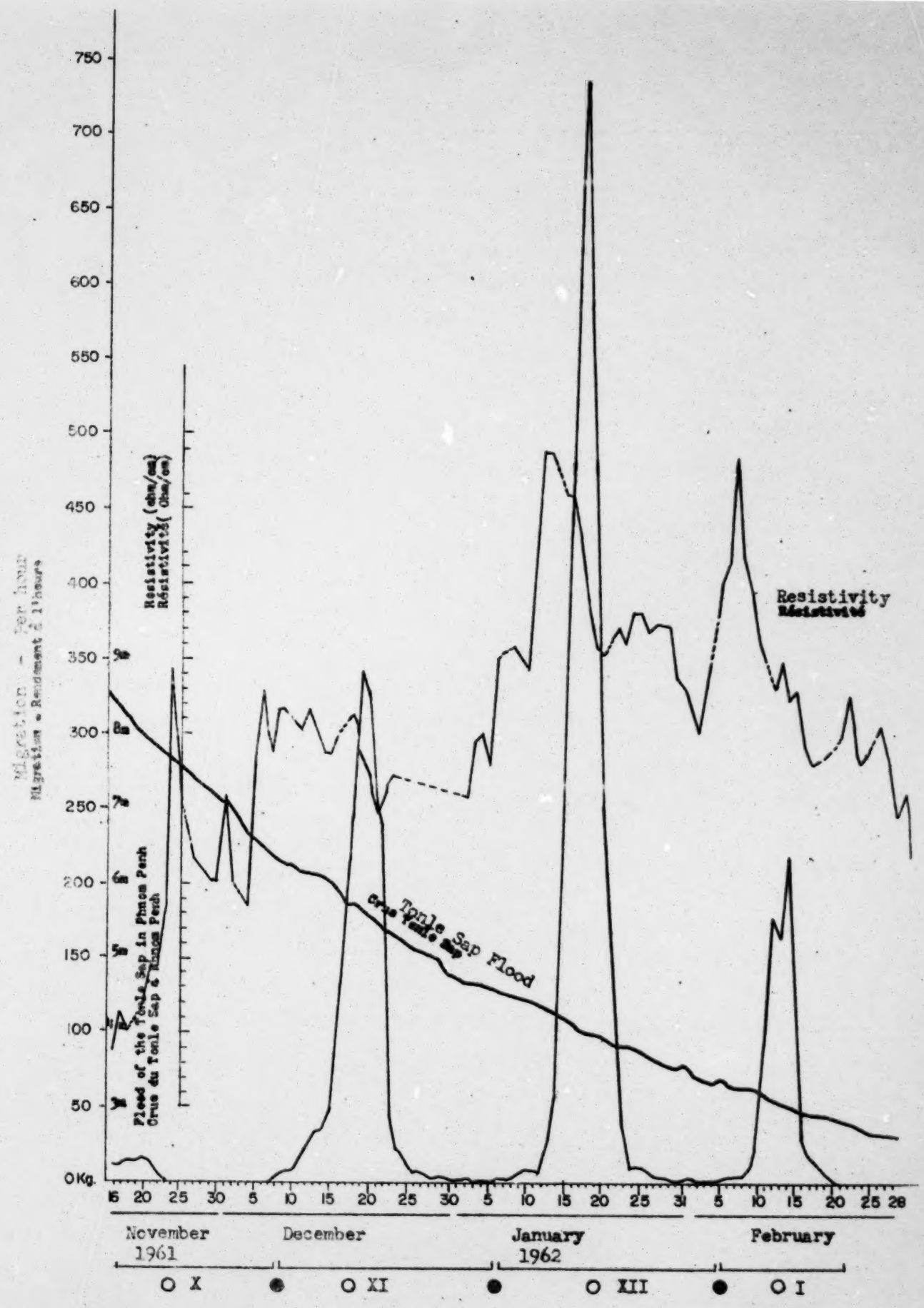
IV. The Pangasius, Cirrhinus, Catlacarpio, Pangasianodon gigas, Probarbus julieni, have a breeding season, starting with the beginning of the high water stages, i,e, from June to end September. Others, like Osteochilus melanopleura, Labeo kruyophokadion, Puntius altus, Puntius bramoides, lay practically until the month of February. Others like Alosa, Coilia, Setipina, lay in the river from April and continue later in the Lake (many mature females are still found in October).

V. Flood migrations are controlled by the mechanical effect of the water. The fish allow themselves to be carried along by the flood stream.

VI. The ebb migrations are regulated by the rythm of lunar phases (see chart). The passages from the flooded areas into the river and stung mostly occurred from the 8th to the 15th lunar day of the 10th, 11th and 12th Chinese months. The passages into the river and the stungs vary according to the spot where the fish come out from the flooded area. Thus, fish schools coming out of the Tonle Sap in Phnom Penh between the 8th and 15th lunar day will be fished in the Mekong at Kompong Cham from the 18th to the 20th day, and downstream from Kratié on the 25th lunar day and subsequent days.

VII. According to our first observations, Cirrhinus auratus raised a physiological problem as this fish migrated as far as the Khone Falls where full sized specimens had been caught, whereas no mature adult had been reported in the Great Lake. We had classified it as having a biology similar to that of Salmonidae. Actually, Cirrhinus auratus also lays in the flooded area of the Great Lake. The fishing done at Snoc Trou during the flood enabled us to catch mature specimens and we also observed in the flooded forest many schools of Cirrhinus fingerlings.

/ This


Migration - Per hour
Migration - Rendement à l'heure
Resistivity (ohm/cm)
Résistivité (Ohm/cm)
Flood of the Tonle Sap in Phnom Penh
Crue du Tonle Sap à Phnom Penh
Tonle Sap Flood
Crue du Tonle Sap
Resistivity
Résistivité
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0 Kg.
15 20 25 30 5 10 15 20 25 30 5 10 15 20 25 31 5 10 15 20 25 28
November 1961
December
January 1962
February
O X
O XI
O XII
O I

This did not prove that it was not necessary for this fish to travel the rapids for physiological reasons connected with the maturing of their gonads. This is why we raised in closed waters 50 adults caught in the Tonle Sap at the time of ebb migration. Every third month from January 1961 to July 1963 (2½ years) we dissected several of them. Not until July 1963 did we find a marked evolution in the gonads. This experiment tends to show that the presence of Cirrhinus in the rapids is not indispensable from a genital viewpoint and that an adaptation to closed waters is possible.

Migrations rules

I. When the flood comes, the fish seek to reach the flooded areas. They move with the flood, that is with the current.

II. When water recedes, the fish leave the flooded areas and wait in free water areas (Great Lake, Beng, Tonle Sap). Then, they descend with the water according to lunar rythms until they meet continuous watercourses (river, tributaries, defluents, stungs), where they move against the current.

CONCLUSION:

I. The Tonle Sap is part of the flood system. The fish move in the same direction as its waters both during the flood and receding periods. There consequently is no need to provide ladders to help the movement of the fish, as the mere opening of the lock doors will be sufficient. On the other hand, it will be necessary to provide ladders, lifts, or locks on all the projects which might be constructed on the river or on the stungs.

II. We find that the quantities of fish entering the Lake are small. A significant portion of the flood migration scatters in the great flooded area of the meanders of the Tonle Sap and of the delta of Stung Chinit, then of the Veal Pok.

The interest of the migration is essentially the passage of adult Pangasius sutchi, Catlacarpio, Pangasianodon gigas, Cirrhinus auratus, which cannot under the present conditions stay in the Lake during the low water stages, the other categories being abundantly represented in the Lake.

/ III.

III. The construction of a dam on the Tonle Sap raises no difficulties in respect of fish migration if this dam is located as far as possible from Quatre-Bras. The suggested construction upstream of Kompong Chhnang therefore is desirable.

IV. We maintain our advice, expressed in a first report, to maintain in the Lake a depth of 2 meters in the low water stages so that the adults of the most interesting varieties, especially Pangasius sutchi, may remain there.

Our observations also enabled us to foresee that a number of species such as Puntius bramoides, Puntius altus, Cyclocheilichtys enoplos, Osteochilus melanopleura, Labeo krysophekadion, Clupea thibeaudeaui, will be able, owing to the favourable environment made available to them, to continue laying in the Lake whereas the mature adults which we found were outside the Lake during the months of January - February; this would have the advantage of reducing the importance of the migration and of gaining a few months (4 months) on an early life which could from the start be provided with a more stable environment. Another significant benefit would be the preservation and the possibility of transporting in fish-wells of the living fish, which is currently impossible during the low water stages.

V. It is necessary to preserve as best as one can the flooding process, responsible for the nutrient power of the Lake waters.

VI. It is essential to take into account the demand made on the fish stock and the adaptation of the human factor to the new milieu resulting from the construction of the dam.

TABLE OF MIGRATIONS

M E K O N G

1st sector

flood migrations

- Longitudinal - passing to 2nd sector; downstream. — downstream
- Transversal - entering the preks, the O and submerged islands.

ebb migrations

- Longitudinal - return from 2nd sector, upstream. — upstream
- Transversal - return from the preks and O to the Mekong.

low water stages

I - Concentration in still and deep areas.
II - Fish retained in the dead arms.

2nd sector

flood migrations

- Longitudinal - passing from 1st sector, passing into the Tonle Sap via Great Lake — downstream
- Transversal - entering the preks, bengs and flooded area.

ebb migrations

- Longitudinal - return of fish from the Tonle Sap. upstream travelling of some fish into Sector 1. — upstream
- Transversal - return flooded area of bengs, preks, towards the Mekong. upstream travelling of some of the fish into Sector 1 resumed by longitudinal migrations.

low water stages

I - Stabulation in still areas with passing from one area to another.
II - Continuous movement between Kratié and Quatre-Bras.

T O N L E - S A P

flood	1st stage migrations	Longitudinal	- towards the Great Lake
		Transversal	- entering the preks and bengs, then into flooded area.
	2nd stage migrations	Longitudinal	- for fish coming from Mekong (1st & 2nd sector) and going to the Great Lake.
		Transversal	- for fish coming from Mekong (1st & 2nd sector) and entering the preks, bengs and flooded areas.
ebb	migrations	Longitudinal	- gradual; large species november-december; small species in the 2 next months towards the Mekong (2nd & 1st sector) — lunar phases
		Transversal	- beginning with the early stages of the receding of the water from flooded areas, bengs and preks, towards Tonle Sap — lunar phases
low water stages	migrations	Few movements; according to their size, the fish are remaining in more or less deep areas.	

G R E A T L A K E

flood	migrations	<u>Longitudinal</u> : I - Fish coming from Tonle Sap and stungs. II - Fish coming from the Mekong, sector 1 & 2. <u>Transversal</u> - very important around the flooded forest; the distribution of fish is limited to the proportion of dissolved oxygen.
ebb	migrations	<u>Longitudinal</u> - slow & gradual; the big specimens first Great Lake, Tonle Sap, Mekong (1 & 2) and stungs. <u>Transversal</u> - from the flooded forest to the Great Lake or to the stungs (lunar phases).
low water stage		Almost all varieties are represented in the Great Lake; including the small specimens of the big varieties. Formation of schools; movement connected with accumulations of phytoplancton.

PLAN FOR THE OPERATION OF THE PROPOSED DAM ON THE TONLE SAP

The plan of operation we suggest is divided into two parts. The first part provides for a gradual start, leading to the final operating plan.

In our suggestions, we solely consider the fish and the implications for fishing.

The plan must essentially reckon with the fishing factor for, if the demand on the current stock was to cease, a biological unbalance would follow owing to the excess requirement in relation to the amount of food available.

We suggested a period of three years for the determination of the final operation plan, which would make it possible to watch the progress of the adaptation of fish to new conditions, as well as any other aspect of the dam: agriculture - navigation - energy.

(a) Flood

The arrival of the (red) Mekong waters at Snoc Trou on 19 June 1962 (elevation 4.69 m) corresponds to several important passages from 19 to 29 June. It would be essential for the dam to be opened when this water is reported at Prek Kdam, and to keep the dam open for ten days. Then, until the end of August, three or four gates should be lifted on a minimum height of 3 m. in places selected in the deepest spots, to allow the very big fish varieties, such as the Pangasianodon gigas and Catlacarpii, to get through. The fishing done at Snoc Trou led to the catching of Pangasianodon gigas from early July to the end of August, the water being afterwards too high for the good operation of the fishing devices.

It is obvious that the dam can be opened over the whole flood period for other purposes. However, the rising of the waters in the flooded forest will have to be controlled, so that it is made gradual with a view to prevent pollution risks.

The maximum flood level will, on an average, be according to the data made available to us, 1.5 m. lower than what it currently is. This loss in level will be largely compensated by the retaining of the anticipated maximum for a two months' period.

/ To ensure

1961	January J31	February J28	March J31	April J30	May J31	June J30	July J31	August J31	September J30	October J31	November J30	December J31
1	15	16	15	16	17	18	19	20	22	22	23	24
2	16	17	16	17	18	19	20	21	23	23	24	25
3	17	18	17	18	19	20	21	22	24	24	25	26
4	18	19	18	19	20	21	22	23	25	25	26	27
5	19	20	19	20	21	22	23	24	26	26	27	28
6	20	21	20	21	22	23	24	25	27	27	28	29
7	21	22	21	22	23	24	25	26	28	28	29	30
8	22	23	22	23	24	25	26	27	29	29	1	1
9	23	24	23	24	25	26	27	28	30	30	2	2
10	24	25	24	25	26	27	28	29	1	1	3	3
11	25	26	25	26	27	28	29	1	2	2	4	4
12	26	27	26	27	28	29	30	2	3	3	5	5
13	27	28	27	28	29	1	1	3	4	4	6	6
14	28	29	28	29	30	2	2	4	5	5	7	7
15	29	1	29	1	1	3	3	5	6	6	8	8
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28	12	14	12	14	14	16	16	18	19	19	21	21
29	13		13	15	15	17	17	19	20	20	22	22
30	14		14	16	16	18	18	20	21	21	23	23
31	15		15		17		19	21		22		24
Month Nos	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	X

migrations

migrations

1962	January	February	March	April	May	June	July	August	September	October	November
	J31	J28	J31	J30	J31	J30	J31	J31	J30	J31	J30
1	25	27	25	27	27	29	30	2	3		
2	26	28	26	28	28	1	1	3	4		
3	27	29	27	29	29	2	2	4	5		
4	28	30	28	30	1	3	3	5	6		
5	29	1	29	1	2	4	4	6	7		
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13	8	9	8	9	10	12	12	14	15		
14	9	10	9	10	11	13	13	15	16		
15	10	11	10	11	12	14	14	16	17		
16	11	12	11	12	13	15	15	17	18		
17	12	13	12	13	14	16	16	18	19		
18	13	14	13	14	15	17	17	19	20		
19	14	15	14	15	16	18	18	20	21		
20	15	16	15	16	17	19	19	21	22		
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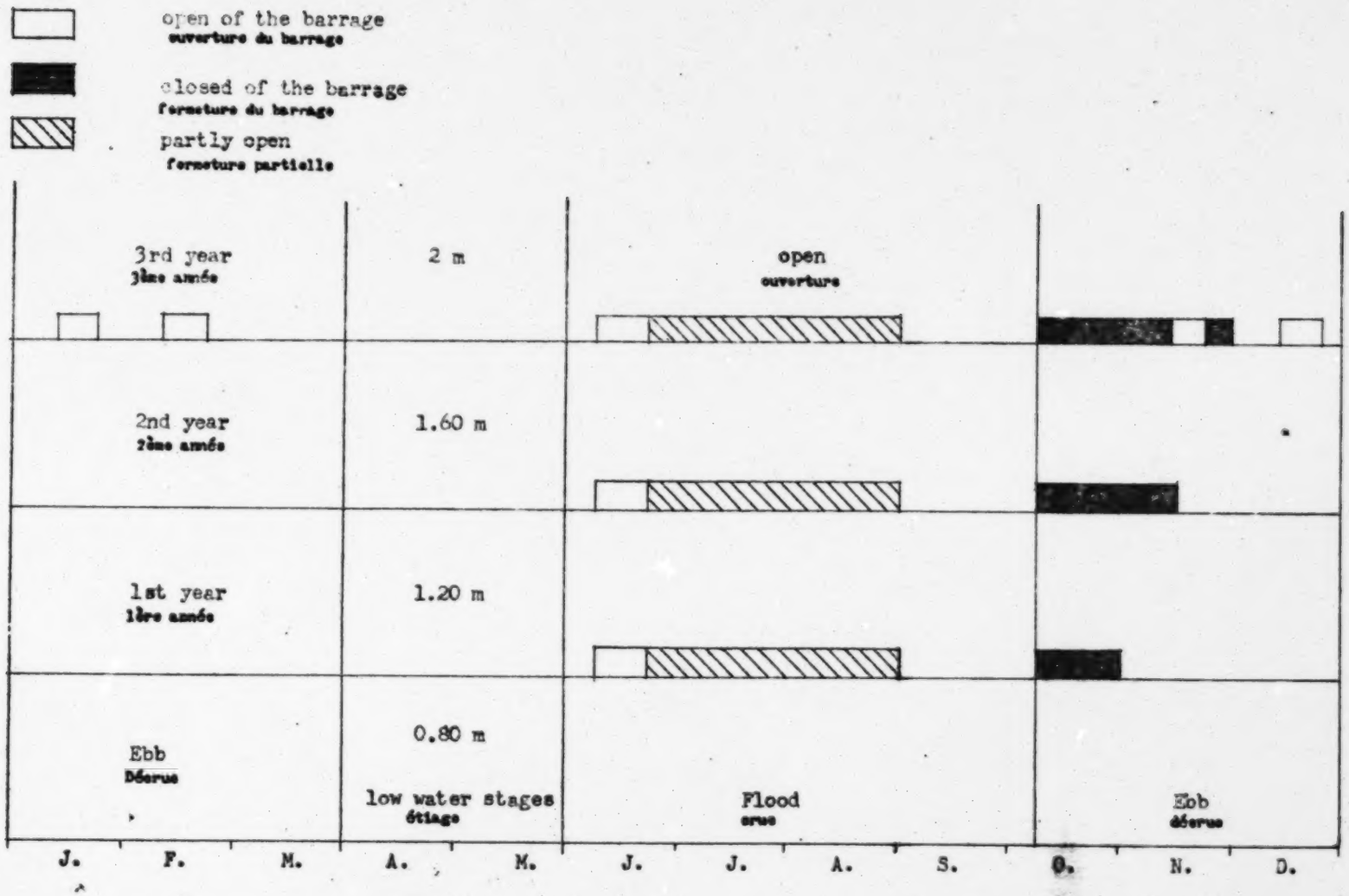
27	22	23	22	23	24	26	26	28	29		
28	23	24	23	24	25	27	27	29	30		
29	24		24	25	26	28	28	30	1		
30	25		25	26	27	29	29	1	2		
31	26		26		28		1	2			
Month	XII	I	II	III	IV	V	VI	VII	VIII		
Mois											

migrations

migrations


open of the barrage
ouverture du barrage
closed of the barrage
fermeture du barrage
partly open
fermeture partielle
3rd year
3ème année
2 m
open
ouverture
2nd year
2ème année
1.60 m
1st year
1ère année
1.20 m
Ebb
Décrue
0.80 m
low water stages
étiage
Flood
crue
Ebb
décrue
J.
F.
M.
A.
M.
J.
J.
A.
S.
O.
N.
D.

To ensure a gradual start, it would be advisable to leave the dam closed during the first year until the end of October; during the second year, until the 10th or 15th November, and, during the third year, until 1st December.

(b) Receding stages

During the receding stages, favourable passage periods in relation to lunar phases will be taken into account. If we take as an example the years 1961-1962 (see chart) the migration will take place:

From 12 Nov. - 22 Nov.	- 5th lunar day of the 10th month to 15th " " " " "
" 12 Dec. - 22 Dec.	- 5th lunar day of the 11th month to 15th " " " " "
" 10 Jan. - 20 Jan.	- 5th lunar day of the 12th month to 15th " " " " "
" 9 Feb. - 19 Feb.	- 5th lunar day of the 1st month to 15th " " " " "

These opening dates in relation to lunar phases will have to be respected for the passages to take place normally. Outside these dates, the gates can be operated in any way deemed necessary to suit other requirements.

Low water stages

This is the time of the greatest fishing activity on the Lake. A period of 3 years' duration to allow fishermen to become adapted to the new suggested condition seems a strict minimum for the gradual development of the lake's edge and the adaption of fishing devices. We suggest:

For the first year	1.20 m.
For the second year	1.60 m.
For the third year	2.00 m.

CONCLUSION

This plan of operation represents, from the basic knowledge acquired, what seems to us most advantageous for fish life. Another plan concerning the flora will be suggested by Mr. Schmid. It will then be possible through a combination of both plans to reach a balanced project.

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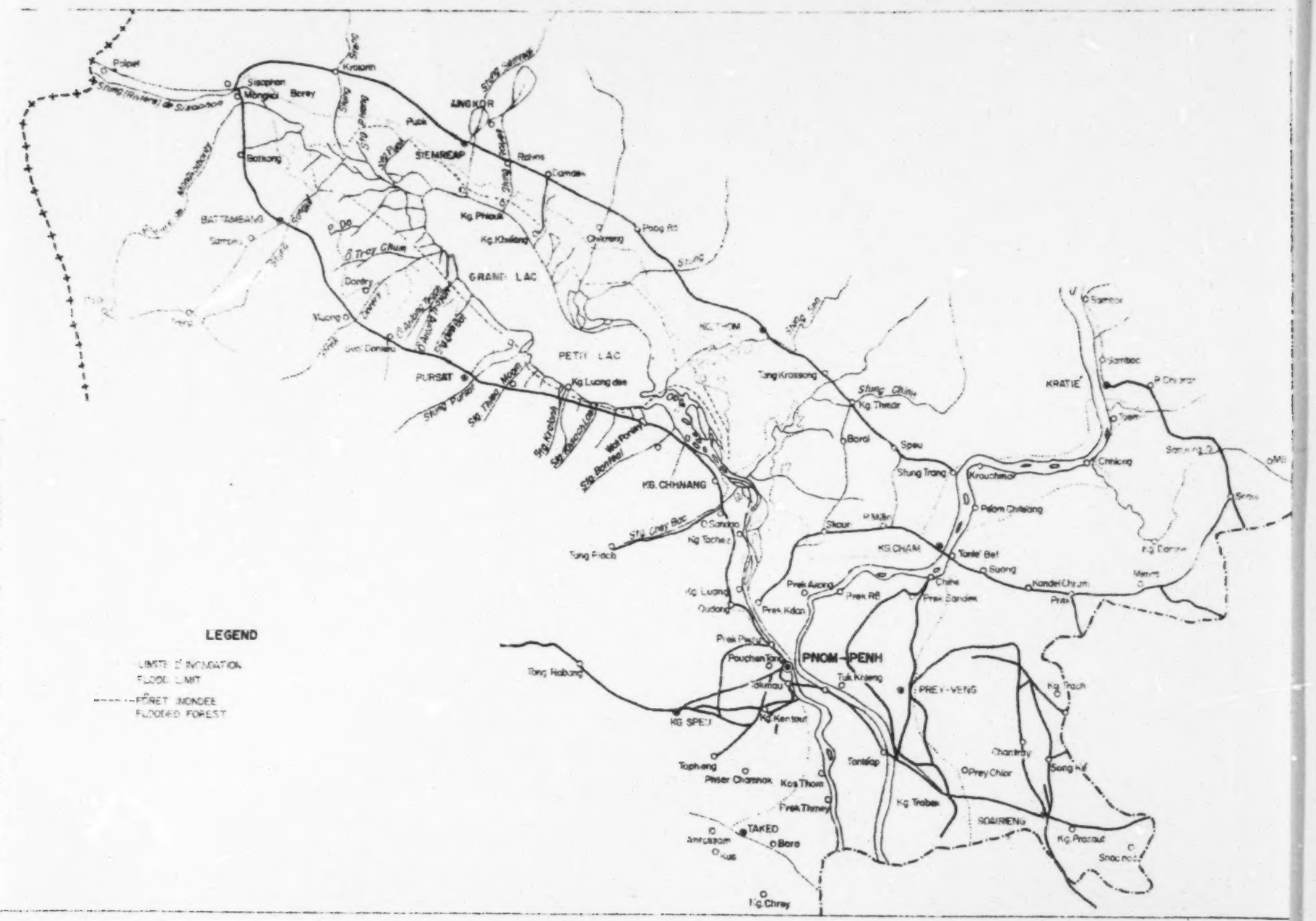

Poipet
Sisophon
Mongkol Borey
Banteay Chhmar
Kralanh
Puok
LING KOR
STEMREAP
Roluos
Damdek
Kg. Phaoul
Kg. Khsiang
Chikreng
Ploeg Ro
BATTAMBANG
Samlaut
Sangke
Moung Russey
Phnom Sorsia
Thnal Totung
Dontry
Kuong
Ang Tasom
Ang Thnot
GRAND LAC
PETIT LAC
PURSAT
Kg Luong dae
Stung Pursat
Stg Thlea Maor
Stg Krakor
Stg Kaoh Sla
Stg Bonteay
KG. CHHNANG
Stg Chey Bac
Sandan
Kg Tachey
Tang Krasang
Stung Chinit
Kg. Thmar
Borei
Speu
Stung Trang
KRATIE
Sambor
Chlong
Krauchmar
Pelam Chhlang
Skaun
KG CHAM
Tonle Bet
Suong
Kandel Chrum
Prek Avong
Prek Rit
Prek Sandek
Kg. Luang
Oudong
Prek Kdam
Prek Preah
Pouchen Tong
PNOM-PENH
Tonle Hlabung
Takmau
Tuk Khleng
PREY-VENG
Kg. Trach
KG. SPEU
Kg Kantout
Chantray
Song Ke
Taphieng
Peser Chamnok
Kos Thom
Prek Thmey
Tonlop
Prey Chor
Kg. Trabek
SOAIRIENG
TAKEO
Bore
Kus
Kg. Chrey
Kg. Prasaut
Snao
LEGEND
LIMITE D'INONDATION
FLOOD LIMIT
FORET INONDEE
FLOODED FOREST

LIMITED

WRK/MKG/INF/L.119
2 January 1964

ORIGINAL : FRENCH

UNITED NATIONS

ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST

Committee for Coordination of Investigations
of the Lower Mekong Basin
(Cambodia, Laos, Thailand and Vietnam)

REPORT ON THE OPERATION OF A BARRAGE ON THE TONLE SAP

by

M. SCHMID
Chief of the Botanical Mission

REPORT ON THE OPERATION OF A BARRAGE ON THE TONLE SAP

Possible implications for the vegetation on the edges of the Tonle Sap of the construction of a dam providing for the regulating of the streamflow of the Lower Mekong

(M. Schmid)

Upon the suggestion of Mr. d'Aubenton, coordinator of the studies on the biology of the fish on which Cambodian fisheries are dependent, I had been asked by the Mekong Committee to study the vegetation under periodical flooding conditions in the vicinity of the Tonle Sap in an attempt to determine the possible implications of the construction of a dam to strengthen the moderating influence of the Great Lake on the Lower Mekong floods on the distribution of the main vegetation groups and, consequently, on the associated fish-life.

In two notes prepared after visits made from 18 May to 2 June 1961 and 12 to 30 November 1962, I had reported on my observations about the connexion between the current distribution of vegetation groups and the variations in the ecological conditions, factors such as the physical conditions, the duration of the flooding periods, the movements of the water, the importance of the silting process... being considered by me as paramount importance.

The knowledge I may have of the behaviour of the most common species is obviously too incomplete for me to perceive always with sufficient clearness the way in which those species would react if the environment to which they are adapted were to be suddenly modified. Furthermore, topographic and sedimentation data available to me are not sufficient to enable me to assess with certainty the changes which, as a result of the operation of the dam, would appear in the different biotopes.

/Nevertheless,

Nevertheless, taking into account the information gathered as well as the most plausible assumptions and these reservations being made, it seems I might to some purpose examine the probable implications on the structure and composition of vegetation of a modification of the hydraulic regime and indicate which pattern of operation would in my opinion be least likely to involve disturbances which might be harmful to fish-life.

Two separate questions arise:

1) What changes will occur in the vegetation following the construction of the barrage? Can the extent of these changes vary with the conditions of utilization of the barrage, it being understood that these conditions are largely determined by the initial purpose of the project, i.e. the control of the Mekong floods?

2) Assuming that the operation of the barrage results in a change of the distribution of the main vegetation groups, coupled with a marked reduction of the areas occupied by some of them, will the fish life be seriously affected by this factor?

Providing the elements of an answer to the first of these questions is the very reason of the survey I was asked to conduct. The second question pertaining to animal biology rather than botany, I shall do no more than submit a few comments on this subject.

I - Implications

I - Implications for the vegetation of the operation of the barrage

From the statement made in Phnom Penh in May 1961, during an experts' meeting, it appears that the operation of the barrage should include 3 main stages: in Spring, the closing of the gates would prevent the first flood water from passing from the Mekong into the Great Lake. A little later, the gates being opened, the Summer floods, whose volume is much greater, could be absorbed by the depression of the Tonle Sap all the better as the water levels, across the dam - a difference which would have gradually increased during the first stage - would be greater. Lastly, during the ultimate phase, the dam would have a controlling and slowing down effect on the receding flow.

At the end of the receding stages, the water of the Lake would be kept at a level 1.50 m higher than the low water level under natural conditions, because of the beneficial effects of such a scheme on fish life. Conversely, the operation of the barrage would entail a slight lowering of the maximum level reached by the water, this lowering being to some extent compensated, as regards vegetation on the edge of the flooded zone, by an extension of the duration of the high water period.

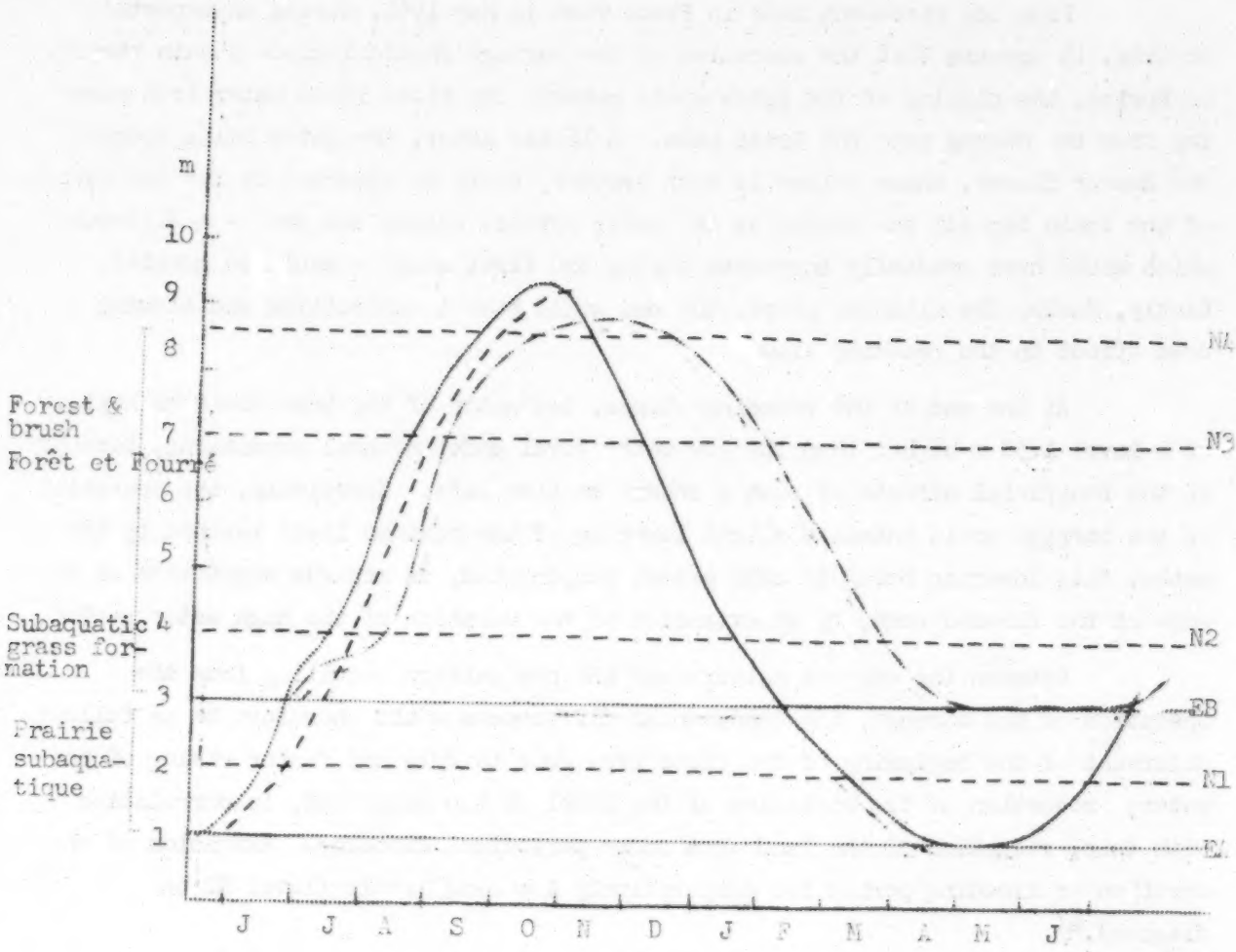
Between the current pattern and the new pattern resulting from the operation of the barrage, the fundamental differences would therefore be as follows: deferment of the beginning of the flood from June to July and faster rising of the water; reduction of the variation of the level of the water and, in correlation with this, reduction of the land area under periodical flooding. Extension of the duration of flooding period for comparatively low land levels (level N2 on diagram).1/

/The main characteristics

1/ Through the extension of the ebb period, soft water pressure in the lower delta would longer remain sufficient to prevent the intrusions of brackish or acid water. However, the slowing down of the emptying process of the water of the Lake might have some unfavourable effects in connexion with the sedimentation and slow down the evacuation of the polluted water which tends to accumulate in some poorly drained areas.

Variations of the water level of the Great Lake during the year (in the vicinity of Snoc Trou)

Variations de niveau des eaux du Grand Lac au cours de l'année (au voisinage de Snoc-Trou)



——— Régime 1962 Regime 1962

- - - Régime 1963 Regime 1963

..... Régime prévu (d'après l'exposé sommaire du plan indien et compte tenu des recommandations de M. d'AUBENTON)

.nticipated regime (from the outline contained in the Indian plan and taking into account Mr. d'Aubenton's recommendations)

E_A - Niveau d'étiage actuel. Present low water level

E_B - Niveau prévu. .nticipated water level

The main characteristics of the vegetation may now be recalled:

The flora is rather original but seems comparatively poor. This originality and this lack of variety show that the conditions to which the species are preadapted are very special.

The structure and the composition of the vegetation vary according to the regime of floods. Some groups are aquatic, some are semi-aquatic, others are amphibious, the latter, which constitute what is called the flooded forest, playing in connexion with physionomy by far the most important part.

Among the varieties included in the different groups, some appear to be linked to environment conditions only fulfilled in very localised areas; some others, either by reason of their more adaptable nature or because the conditions they require are less closely connected with local factors, are much more widely distributed; different kinds characteristic of the flooded forest (Barringtonia, Diospyros, Coccoceras...), different shrubs and lianas belong to this second group. Excepting perhaps a few aquatic plants, the species included in the flora of the Tonle Sap could not live in stagnant water.[1/] Their development cycles appear to be conditioned to a greater extent by the pattern of floods than by the climate: the stolons of the subaquatic graminaceae extend as the water rises; their inflorescences appear at the moment when the flood reaches its maximum level; most of the ligneous species, on the other hand, flower when their stems are no longer covered by the water.[2/] The height at which trees ramify varies with the level reached by the water during the flood period, the lowest branches generally being in the vicinity of this level. The trees retain their leaves all the year round; the shrubs which are entirely covered by the flood grow a new foliage when the water has receded. The standing grass, perennial or annual, which grows on the low lands or on some alluvial banks, have a very short development cycle and disappear in the early stages of the flood. Among the subaquatic stoloniferous plants, some become assimilated to the standing grass, during the low

/water stages,

1/ The ligneous varieties do not have pneumatophores.

2/ The flowering induced by the high and dry period may appear shortly after the return of the water, especially for trees, which react much less rapidly than shrubs.

water stages, while some others disappear; one should however not be led to the conclusion that the high and dry period is not necessary for the completion of their cycle.

In the light of these factors, the following observations may be made:

The operation of the dam may deeply disturb plant life on the lowest lands levels (levels N1 and N2): on the one hand the extension of the area permanently covered by water will result in the withdrawal of the flooded forest and the subaquatic grass formation; on the other hand, the extension of the duration of the flood period on lands periodically above water level will result in the disappearance of some varieties. It may also be feared that the rising of the low water level should make more difficult the evacuation of the water bearing organic matter, and more or less acid, which has a tendency to stagnate in the flooded forest. The speeding up of the rising of the water at the beginning of the flood period may indeed hamper the development of subaquatic stoloniferous varieties as well as of some shrubs (Sesbania) whose rate of growth is sufficient, under natural conditions, to keep them from being submerged.

It is true that the stoloniferous graminaceae of the Tonle Sap are also found in the regions where floods are much more sudden. As regards trees, whose crest spreads above the level of the highest water, and the shrubs, which are completely submerged during the flood period, it does not seem that this speeding up of the rise of the water could be very harmful. The deferment of the low water period from February-June to April-July does not seem of a nature to hurt many varieties, as the reproduction cycles seem to have more connection with the rise and fall pattern of the water than with the climate. It would be more harmful to late flowering species (influence of the summer rains); practically without influence upon herbaceous vegetation (Spring and Autumn flowering). But it is very important that the duration of the high and dry period should not be reduced and even at comparatively low levels (level N2), its extension would even be desirable to offset the consequences of the raising of the water level during the low water period.

/Resuming

Resuming discussion of these data, let us see how the operation of the dam might affect the extension of each one of the groups described in our studies on vegetation.

1) Groups on the Lake's edge

(The area occupied by these groups is not extensive; they might however, considering their location, have a great importance for fish life).

Echinochloa stagnina grass formation.

This semi-aquatic graminaea, with long stolons floating during the flood period, occupies sometimes well ahead of the forest's edge incompletely consolidated alluvial banks slightly above low water level. An elevation of the water level during the low water stages should therefore result at least temporarily in a significant reduction of its extension. It may be that after a few years the raising of the present alluvial banks or the constitution of new banks will promote its reappearance.

There should also be a regression of Sesbania paludosa which is found in the same sites as Echinochloa but further away from the Lake, along the banks of the great preks.

Sphenoclaea, Aeschynomene, Leersia grass formation ...

This group is seen in the same areas as the Echinochloa, but its period of active life coincides with the low water season. It should disappear as long as the alluvial beds barely emerging in the low water stages and which constitute its preferential ground have not been reconstituted (delta of Snoc-Trou).

Ficus heterophylla brush ...

This formation, mostly seen along alluvial banks emerging well above low water level and in process of consolidation, could be fairly easily reconstituted as a transfer to the higher reaches of its current home generally seems to be possible. It thus would penetrate into the Sorghum zones which are now cultivated during the low water period (Snoc-Trou delta).

/2) The "flooded forest"

2) The "flooded forest"

This formation includes trees whose trunks, and sometimes for a short period the lowest branches, are submerged in flood periods, as well as an undergrowth of shrubs and lianas which completely disappears during the high water stages. As a result of the destruction of the forest by man, there develops a brush that is difficult to penetrate. It is likely that the undergrowth or brush elements play the greatest part in connexion with fish life.

Both forest and substitution brush grow on already consolidated alluvia. These are amphibious formations, as most of their constituting elements seem to be able to thrive on lands with fairly different flooding patterns. It may however be observed that the composition of vegetation varies as one gets closer to the limits of the flooding zone; it also varies as one moves away from the edges of the Lake or the banks of the preks (less mobile and less aerated water). It does not look as if these variations as such could be of great significance in relation to fish life.

It thus seems that the operation of the dam would not induce spectacular changes in the vegetation, as far as the "flooded forest" is concerned. The fringes would fall some way back, at distances varying with topographical conditions; but the implications of this withdrawal, in the light of the importance of all areas occupied, cannot be very serious for fish life as few species, according to Mr. d'Aubenton, enter very deeply into the clumps. In many sectors, this withdrawal would anyway not be immediate, some marginal species appearing to be able to live on for several years on permanently submerged land. There also would be a process of vegetation transfer, the varieties which currently are most abundant on the edge of the Lake tending to replace on the intermediate levels between N2 and N3 (see diagram) varieties more susceptible to prolonged immersion. On the fringes of the flooded zone, no significant changes would be noted.

3) Herbaceous

3) Herbaceous aquatic or subaquatic groups of the bongs

Floating or submerged aquatic grass formations.

Their development should be promoted by the raising of the low water level and the slowing down of the evacuation of water when flood water recedes. The increase in the superficy of current permanent or temporary ponds will have in this respect less significance than the creation of new pools of still water, for aquatic grass formations, perhaps because of their susceptibility to the action of the winds on the water, cannot wholly occupy water expanses above a given size.

Subaquatic grass formations.

(Mostly Graminaceae: Sacciolepis...)

Vegetation in these formations is constituted by stoloniferous kinds with ecological requirements similar to those of Echinochloa stagnina but whose development is interfered with by the agitation of the water and which, on the other hand, do well in comparatively acid and poorly aerated water. They can be seen in spots inside the forest, particularly in the west (sector of Prek Préas Dam and in the north of the small Lake); they grow extensively on the limits of the flood zone where peripheral water collects in troughs, which drup up later and less completely than "flooded forest" lands.

As the operation of the dam would slow down the evacuation of the water from these troughs, it might promote at the expense of Graminaceae the extension of the aquatic grass formation area. But it is chiefly for grass formations located inside the forest that a reduction of the oxygen content of the water and the resulting pollution might be feared. The grass formations on the edge of the flood area being probably at a comparatively high level, it on the contrary is the improvement of the draining conditions resulting from a lowering of the maximum flood level which could lead to their regression.

/4) Subaquatic groups

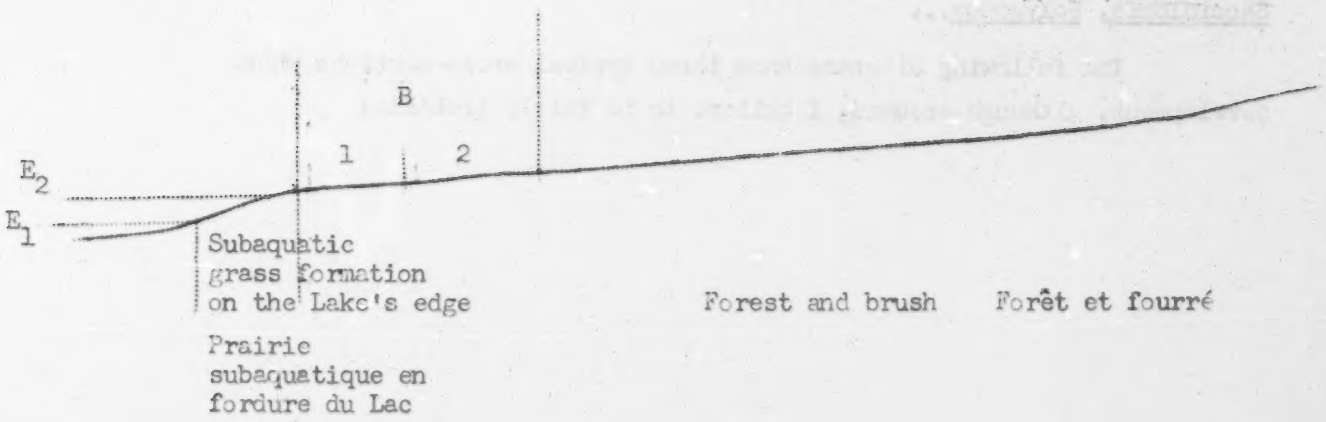
4) Subaquatic groups of the banks

The raising of the low water level should induce a slight displacement of the Polygonum and Achyranthes groups, commonly seen along the preks, without bringing about any significant alterations of their currently occupied area.

In the foregoing remarks, I did not take into account the possible variations from one sector to another of topographical conditions, which may result in either an increase or a reduction of the areas in which the consequences of the operation of the dam would be most clearly felt.

A study conducted by SOGREAH experts, who agreed to let us have some of their results, showed that the extension of the superficy of the flooded zone does not follow a regular pattern in relation to the rising of the water. In the early stages of the flood, the horizontal advance of the water is comparatively slow by comparison with their vertical movement; when the level of the Lake has reached level 3, the horizontal progressive becomes faster, the expanding of the flooded area for a given rise of the water level between levels 4, 5 and 7 being almost three times as great. It later slows down, while remaining in the vicinity of level 9 more rapid than in the vicinity of the low water level.

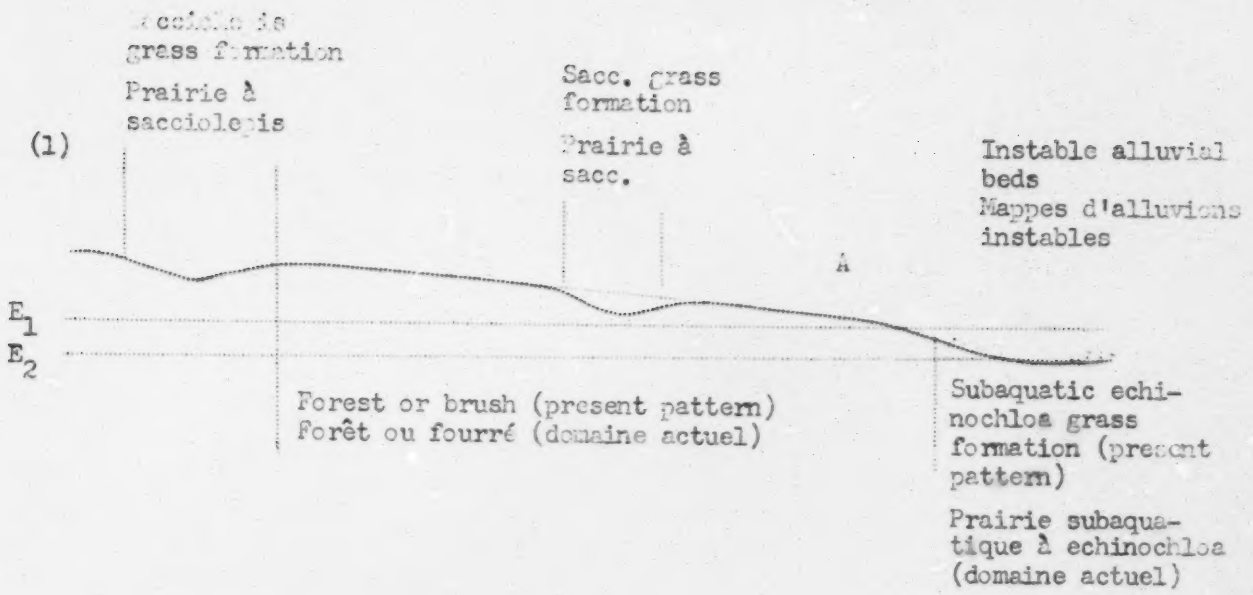
The average topographical cross-section of the edge of the Lake near the limits of the trough would therefore be approximately as follows:


B
1
2
E_2
E_1
Subaquatic grass formation on the Lakc's edge
Prairie subaquatique en fordure du Lac
Forest and brush
Forêt et fourré

On this diagram, it is clear that the raising of the low water level from E1 to E2 would result in the displacement of the subaquatic grass formation (Echinochloa...) from A to B. Actually, its new sector would probably be limited to zone B2. The ligneous groups superficy would diminish from 20 to 30%. After a new equilibrium had set in, vegetation changes would chiefly consist, at least in the forest sector, in the falling back of such species as are ill-adapted to prolonged submersion, those which currently are most abundant in sectors located on the edge of the Lake and most interesting in connexion with fish life being helped by an extension of the duration of the flooding period on the limit of the area covered by the waters.

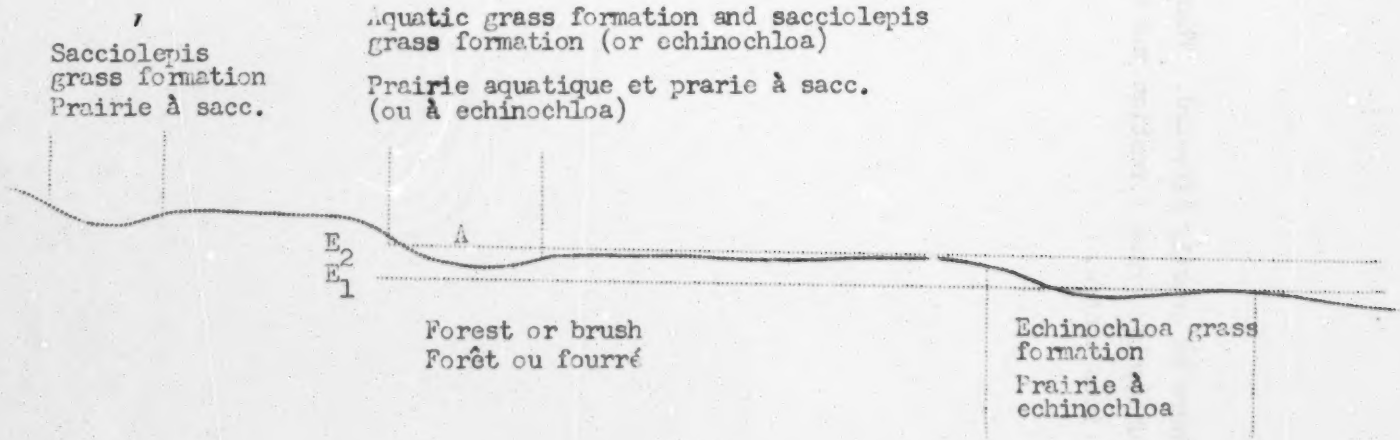
These very general data do not consider local topographical variations which, while they influence the distribution of the above mentioned groups, are determining for the existence of aquatic and subaquatic grass formations with Sacciolepis, Polygonum...

The following diagrams show three typical cross-sections whose development, although assumed, I believe to be fairly probable:


Saccio.le
grass formation
Prairie à
sacciolepis
(1)
Sacc. grass
formation
Prairie à
sacc.
Instable alluvial
beds
Mappes d'alluvions
instables
A
E_1
E_2
Forest or brush (present pattern)
Forêt ou fourré (domaine actuel)
Subaquatic echi-
nochloa grass
formation (present
pattern)
Prairie subaqua-
tique à echinochloa
(domaine actuel)

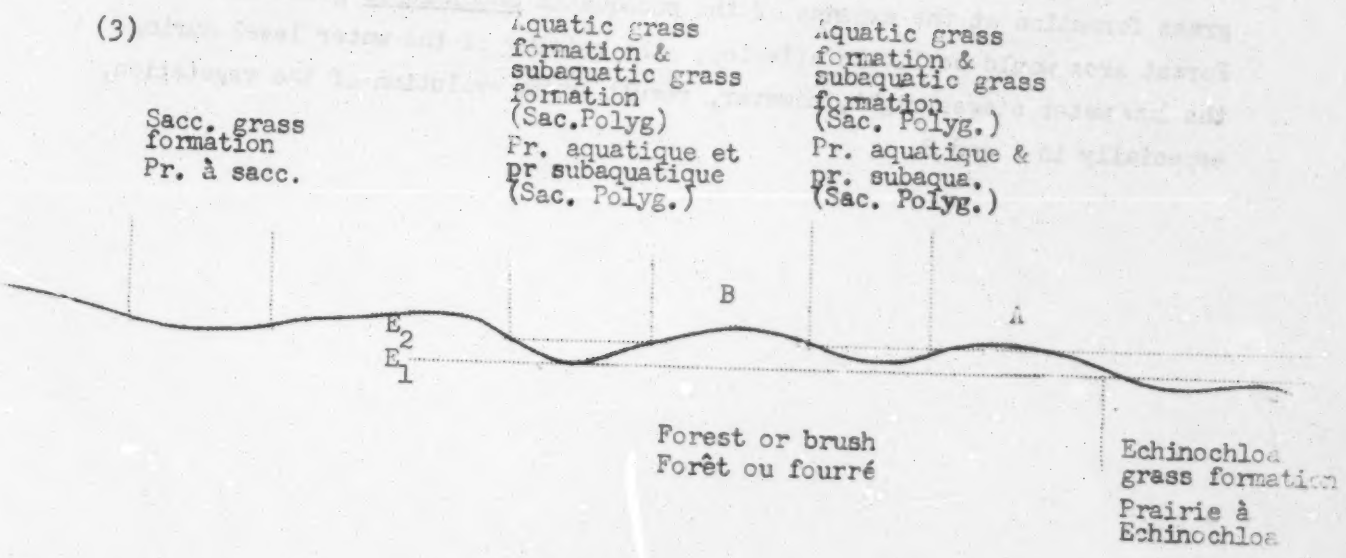
The raising of the low water level from E1 to E2 will more or less affect the forest area according to the angle and length of the slope in A. The Sacciolepis grass formation will not be much affected.

(2)


Sacciolepis
grass formation
Prairie à sacc.
Aquatic grass formation and sacciolepis
grass formation (or echinochloa)
Prairie aquatique et prarie à sacc.
(ou à echinochloa)
A
E2
E1
Forest or brush
Forêt ou fourré
Echinochloa grass
formation
Prairie à
echinochloa

The forest area would here be greatly affected. There probably would be a regression of the subaquatic grass formation and a transfer of Echinochloa grass formation into zone A.

(3)


Sacc. grass formation
Pr. à sacc.
Aquatic grass formation & subaquatic grass formation (Sac.Polyg)
Pr. aquatique et pr subaquatique (Sac. Polyg.)
Aquatic grass formation & subaquatic grass formation (Sac. Polyg.)
Pr. aquatique & pr. subaqua. (Sac. Polyg.)
B
A
E2
E1
Forest or brush
Forêt ou fourré
Echinochloa grass formation
Prairie à Echinochloa

Probable extension, after the barrage had started operation, of the aquatic grass formation at the expense of the subaquatic Sacciolepis grassland. Forest area would be little affected; the raising of the water level during the low water stages might, however, result in an evolution of the vegetation, especially in A and B.

II - Implications for fish life

It is understood that vegetation largely conditions the living of the fish of the Great Lake; however, one knows nothing about the part played by specific varieties or vegetation groupes.

The ligneous varieties can only indirectly contribute to the feeding of the fish; tree leaves remain permanently above water level and shrub leaves are not renewed until the beginning of the period of emersion. The part played by the subaquatic grass formation does not seem either to be very important (tough grained stolons, at least in the case of the Graminaceae, stems bearing leaves and flowers sticking out of the water); the part played by the aquatic grass formation, especially in case of submerged groups (Ceratophyllum group) is undoubtedly not negligible, but remains secondary. On the other hand, the decaying of huge masses of loose vegetable débris, either when the water rises (leaves of the brush and undergrowth), or during the low water stages (case of the subaquatic grass formation), makes possible the development of an abundant plancton.

The commissioning of the dam, by reducing the yearly amplitude of the water level variation, might cause a reduction in the quantities of organic matter available to the plancton in the development of which autotrophic organisms would therefore play a more important part, a result which in itself is of little consequence.

One should however not forget to consider the possible changes in the quality of the water penetrating into the Great Lake: the content of this water in some specific elements still largely conditions plant life and, to an even larger unit, the development of the plancton, as the decaying process of organic matter as well as the multiplication of autotrophic organisms are basically dependent on this.

Analysis made in 1962 by the Institut Paster upon the request of Mr. d'AUBENTON have shown a sharp reduction in the Ca^{++} content of the water of the Tonle Sap in Phnom Penh, at the beginning of the flood period.(1)

/ We thus

(1) The amount of dissolved mineral substances is in the water of the Tonle Sap very similar to that of the water of the Mekong throughout the flood period; it is much lower during the ebb period and during most of the low water stages.

We thus see that the Ca^{++} content falls from 20.8 mg.l in May (15 May) to 10.4 in June (15 June); it increases later to settle in the vicinity of 15 in July-August, and 18 in September. It falls when the water has reached its maximum level and remains around 9 during the ebb and low water periods, their sharp rise in May indicating the first stages of the penetration of the water of the Mekong, slightly ahead of the flood. Although the Mg^{++}, Na^{+} and K^{+} content does not show similar variations, this fall ofthe content in Ca^{++} in June goes together with a sharp reduction of the overall alcalinity.

One might feel inclined to conclude that, as the closing of the dam at the beginning of the flood period prevents the penetration of the comparatively demineralized waters, its impact on the fish life in the Great Lake can only be beneficial.

Mr. d'AUBENTON recommends to leave the dam open in the first stages of the flood because of the importance of fish migrations at that time; but there is no certainty that in Snoc Trou the arrival of the fish coincides with that of the water with a low Ca^{++} content.

CONCLUSIONS

The commissioning of a dam for controlling the Lower Mekong floods will necessarily bring some changes in the composition and the distribution of the plant groups occupying the depression of the Tonle Sap.

These changes will be felt all the more as the raising of the low water level will be more significant.

They will be conditioned by the extension of the submersion period, by the raising of the water level during the emersion period, and, lastly, to a lesser extent, by the difference in the average percentages of useful substances between the water which now flows from the Mekong into the Lake and the water which the dam will let pass into it.

If, according to the recommendations of the Chief of the Ichthyological Mission, the new low water level upstream of the dam reaches an elevation of 3 metres, it may be assumed that the current superficy of the flooded forest would be reduced by 20 to 30 %. The area occupied by the subaquatic grass formation on the edges of the Lake, the area occupied by the groups of the preks and bengs, undergo appreciable changes, but these changes would result in displacements rather than a regression. Ultimately, once the transformations required for the adaptation to new environment conditions had been made - transformations which, in the case of the forest, could extend over several tens of years and which, in the case of the herbaceous vegetation, in priciple fairly rapid, could also be of long duration owing to the intervention of sedimentation processes, it does not seem as if they could at more or less long term result in an impoverishment of fish life.

The commissioning of the dam will, however, mark the beginning of a crisis period. With a view to lessening the impact, the raising of the low water level should be effected only gradually. It is essential that the period between the end of the ebb period and the reopening of the dam should extend over 2 months at least, a period of 3 months being preferable. It also is important that the rise

/ of the water

of the water following upon the opening of the dam should not be too rapid. A 1 month to 6 weeks postponement of the low water period, from the beginning of April to March, should not have very unfavorable consequences. An extension of the maximum water level period would be beneficial to the development on the bor[illegible] of the flooded zone of the varieties now abundant in the sectors most assiduously visited by the fish. The evolution of the vegetation in the areas occupied by the Sacciolepis grass formation, because of the lack of sufficiently detailed topographic data, is difficult to foretell whatever the pattern advocated for the operation of the dam, however, assuming that these advantages of the commissioning of the dam be clearly felt in the locations occupied by groups of this type, it should be possible at least in some cases to counteract the ill-effects through comparatively inexpensive local measures.